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Long Term Monitoring of High Grade Uranium Mill Tailings

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Final Report

for

Canada Centre for Mineral and
Energy Technology
555 Booth Street
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1. INTRODUCTION

The Ontario Research Foundation (ORF) was awarded a contract for "The Long Term Monitoring of High Grade Uranium Mill Tailings", by the Canadian Government (DSS File No. 15SQ.23440-1-9140; DSS Contract Serial No. OSQ-81-00211).

The objective of this program was to assess the effect of layered tailings bed deposition on the volume and quality of runoff, seepage, and radon emissions.

During this project, simulated test results were required to be obtained under three phases:

Phase I:	Mill run conditions,
Phase II:	Mill shutdown conditions, and
Phases III & IV:	Mill decommissioning conditions.

Under Phase I of this program, a pilot plant was operated to process 350 kg of Midwest ore per day for a period of seven days between March 21 and 31, 1982. The tailings produced were deposited over the existing Canada Wide Mines Limited (C.W.M.L.) tailings bed emplaced during the C.W.M.L. pilot plant runs. The solids and liquids deposited in the tailings bed were analyzed for U, As, Ni and Ra-226. Four vertical cores were extracted upon completion of this phase (Phase I) to establish the distribution of U, As, Ni, and Ra-226 within the tailings bed. The physical properties of the cores such as porosity and permeability were also tested to ascertain to what extent they influence the distribution of various elements within the bed. Seepage, runoff and final process effluent solutions were analyzed for U, As, Ni, and Ra-226. The pH value of the solutions was also monitored.

Phase II commenced on April 1, 1982. Mill shutdown conditions were simulated. No further tailings were added to the bed. During Phase II - Part 1 which extended until July 13, 1982, treated effluent solutions were introduced into the bed.

Precipitated solids (e.g. arsenic/radium precipitates) were spread over the bed on July 13, 1982. A period designated Phase II - Part 2, during which no further effluents or precipitates were spread over the bed, was allowed to enable the settling of the effluents and precipitates into the bed. Accelerated Northern Saskatchewan summer climatic conditions were imposed on the tailings facility on initiation of this phase and maintained throughout Phase II and Phase III. Four cores were extracted on the completion of Phase II on July 26, 1982. The U, As, Ni, and Ra-226 content, as well as the pH of the tailings, seepage and runoff solutions, were determined. Radon flux determinations were done on the surface of the bed. Bacteriological tests were also conducted on the tailings.

Phase III commenced on July 27, 1982. The physico-chemical behaviour of the tailings under conditions of mill abandonment were monitored. Accelerated Northern Saskatchewan summer climatic conditions were maintained. One set of four core samples was extracted on January 5, 1983, and a final set of four core samples was extracted on completion of this phase on April 5, 1983. The distribution of U, As, Ni, and Ra-226, and the physical properties of the cores were determined. The U, As, Ni and Ra-226 and pH of seepage and runoff solutions were determined. Radon flux determinations were done on the surface of the bed. Biological testing for microbiological activity in the tailings was also conducted.

This work was reported by the ORF on June 21, 1983 in a report entitled "Long Range Monitoring of High Grade Uranium Mill Tailings - Final Report".

The program was subsequently extended to allow the accumulation of additional data and to establish more firmly trends of migrating elements following accelerated aging of the tailings under abandonment conditions.

Climatic conditions imposed on the tailings during this Phase IV monitoring reflected those prevailing in Northern Saskatchewan accelerated five times. Simulated rainfall was adjusted to a pH of 5.4. In addition, a section of the tailings bed was isolated and subjected to freezing and thawing.

Phase IV - Part 1 (DSS File No. 15SQ-23440-3-9004) commenced immediately upon completion of Phase III, and monitoring continued until mid-July 1983. Results were reported on November 28, 1983 in a report entitled "Monitoring of Pilot Plant Tailings Phase IV - Part 1.

The program was again extended (Phase IV - Part 2) and monitoring recommended during October 1983 under similar accelerated hydro-meteorological conditions as were used during Phase IV - Part 1. In addition to the data collected during the previous extension, Phase IV - Part 2 included geochemical testing to further characterize the tailings bed.

Monitoring was finally concluded in May 1984. The results and conclusions drawn from this final phase of the program are embodied in this report.

2. SUMMARY AND CONCLUSIONS

2.1 Summary

The layered tailings technique for tailings disposal has been studied.

A total of about 11.5 tonnes of processed Northern Saskatchewan uranium ore solids were discharged into the test tailings facility over a porous sand blanket.

The average analysis of the tailings feed was as follows:

Uranium	0.25%
Arsenic	2.1%
Nickel	1.3%
Ra-226	4000 pCi/g

The slurry fed into the tailings pit during the various campaigns varied between 29.1% and 32.6% in solids content. The slurry was neutralized to pH 11 with lime before emplacement. The composition of the neutralized tailing solution was as follows:

Uranium	0.0002 g/L
Ra-226	10 pCi/L
Arsenic	0.0004 g/L
Nickel	0.0002 g/L

Measurements of volume and quality of runoff and seepage from tailings and radon emissions from the surface of the tailings were made. Tests were conducted under mill run conditions (Phase I), mill shutdown conditions (Phase II), and mill decommissioning conditions (Phases III and IV).

During Phases II - IV, Northern Saskatchewan summer hydrometeorological conditions, accelerated five times, were imposed on the tailings bed. Temperatures slightly higher than Northern Saskatchewan summer average temperatures were imposed to obtain typical Northern Saskatchewan evaporation rates.

Vertical core samples were taken on completion of each phase, sectioned and analyzed to determine physical characteristics, including moisture content, permeability, porosity, and particle size distribution. Geochemical and cation exchange studies on selected core samples were conducted.

The uranium, arsenic, nickel and radium-226 contents of the individual core segments were also determined. Selected core samples and composites of seepage and runoff solutions were analyzed more completely, and concentrations of such components as sodium, potassium, magnesium, barium, iron and sulphate were determined.

2.2 Conclusions

Based upon the results of the test program, the following observations are made:

- During deposition, as the thickness of the bed increased, a greater proportion of the tailings effluent solution reported to the runoff than to the seepage.

- The overall average proportion of seepage in the tailings effluent solution after implementation of climatic control was 61%. The proportion of seepage was lower during periods of increased evaporation rate. This is considered to be caused by the upward movement of pore fluids when the evaporation rate increases.

- Encrustations of gypsum and nickel sulphate hydrate formed on the surface of the tailings bed. Large polygonal cracks occurred across the surface of the bed due to shrinkage and swelling which took place during alternate wetting and drying of the surface layer.

- The bed was at all times well drained, and therefore the oxidizing conditions which would be encountered above the water-table are dominant.

- The effectiveness of the tailings test facility in directing rainfall to runoff and away from seepage was low. This may be due to the heterogeneity of the bed, as indicated by tests on core samples. This in turn may be due to the relatively shallow depth of the bed or to the difficulty in placement of tailings layers which seldom allowed steady laminar flow of pulp across the bed.

- The pH of the runoff was fairly stable over the rainfall period, averaging about 7.5. The pH of seepage solution declined over the first fifteen months from about 11 to 7. It stabilized at about 0.4 units lower value than that of the runoff. The initiation of acidified rain did not appear to affect the pH of the tailings effluent solution. The tailings were bulk limed before being deposited on the bed. The gradual decline of seepage pH is considered to result from the slow conversion of calcium hydroxide to calcium carbonate, and subsequently to calcium sulphate.

- During the entire plant abandonment phase 69% of the U, 54% of the As, 65% of the Ni, and 87% of the Ra-226 contained in tailings effluent solution reported to the seepage.

- During the final 7 1/2 months of more stable conditions, the percentages reporting to seepage were 72, 63, 72, 73 for U, As, Ni, and Ra-226 respectively.

- Arsenic and radium concentrations in the test facility runoff and seepage solutions were generally outside acceptable effluent levels as contained in the Metal Mining Liquid Effluent Regulations.

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- During the final 7 1/2 months, concentration of U, Ni, and Ra-226 was higher in the seepage than in the runoff. Average arsenic levels were about equal. Earlier measurements showed Ca, K, Na, and SO_4 to be higher in the seepage, Fe and Ba to be about the same in each, and Mg higher in the runoff. The change from neutral to acidified rain was not marked by changes in solution concentration.

- Permeability tests on core samples of the bed did not demonstrate any trends in permeability with location, depth, or over the sampling period. Nor was any relationship seen between permeability and (as received) moisture content.

- Porosity varied widely throughout the tailings and no systematic relationship was found between porosity and elemental distribution.

- Material in the discharge side of the bed contained a considerably higher fraction of fine material, and a higher moisture content, than material in the feed side. No consistent trend in size with bed depth was found.

- There was a strong correlation between arsenic and nickel content within the bed. Arsenic levels were consistently higher in the discharge end, and nickel levels usually so, than in the feed end. This would seem to result from the tendency of fines, including precipitates, to flow to the downstream portion of the bed.

- Radium concentrations in the bed are strongly correlated with the proportion of fine material. Radium concentrations in the same size fraction tend to increase across the bed from the feed to discharge end.

- No trends of nickel, arsenic or radium concentrations with depth were found.

- Uranium concentrations in the surface layer were generally higher than in samples immediately below and there was a relative uranium deficiency in the upper portion of the bed. These effects were apparent through most of the program.

- A downward migration of calcium, magnesium, potassium and sodium within the bed is indicated.

- Elemental distribution patterns in the freeze-thaw section of the bed were similar to those observed in the normal bed. Freezing significantly reduced radon emanation from the bed surface. The integrity of the core was destroyed by freeze-thaw and porosity and permeability test results were meaningless.

- No thiobacillus ferrooxidans was detected in the tailings bed. Tests established that despite the high arsenic levels, the bed could support these organisms with the addition of nutrients and a lowering of pH. Two cultures identified as Gram negative rods were isolated from the effluent solution.

- X-ray diffraction analysis of sized core samples indicated that quartz was the predominant mineral in the coarser fractions, while the clay group minerals (illite and chlorite), bassanite and ferric arsenate were dominant in the minus 12 micron fractions.

- Cation exchange capacity measurements on bed material showed a strong correlation between exchange capacity and fines content of the samples.

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3. BACKGROUND

3.1 General

Prior to the CANMET program, Canada Wide Mines Limited conducted a pilot plant campaign to extract uranium from a high grade uranium ore at the Ontario Research Foundation. Knight and Piesold acted as their consultants, designing, supervising the construction, and participating in the operation of the tailings pit facility.

A review of Knight and Piesold work is necessary to obtain a complete perspective on the CANMET program. Aspects discussed include:

- the Knight and Piesold tailings pit (lysimeter) design;
- the actual details of the lysimeter constructed at the O.R.F. for the study of tailings disposal during the Canada Wide Mines Limited campaigns;
- the tailings disposal aspect of the C.W.M.L. campaigns 1 and 2. Details of this operation are important because material from these campaigns form the base on which the CANMET tailings were distributed;
- operational aspects of the CANMET pilot plant run during which the top layers of the tailings bed (lysimeter) were generated.

3.2 Knight and Piesold Tailings Pit (Lysimeter) Design Features

3.2.1 Objective

The tailings pit was designed by Knight and Piesold to:

- "provide an accurate representation of the water return from the tailings storage facility in terms of quality and quantity in the waste management circuit;

- provide further information regarding the tailings slurry characteristics, water return and final densities for the design of the prototype tailings storage facility;

- provide a facility for assessing the physical and chemical response of a bed of tailings material under a chosen set of accelerated environmental conditions."

3.2.2 Simulated Environmental Conditions Required During the Canada Wide Mines Limited Campaigns 1 and 2

The following environmental conditions were prescribed by Knight and Piesold for the pilot plant campaign conducted by Canada Wide Mines Limited:

required average pan evaporation rate	10 mm/day,
required rate of water addition for simulated precipitation	0.5 m^3/day.

The above prescribed rates applied to the Canada Wide Mines Limited milling phase only, during which water was being introduced into the tailings pit with the slurry. Building of the tailings pit during the C.W.M.L. campaigns 1 and 2 was carried out by Canada Wide Mines and O.R.F. personnel under the supervision of Knight and Piesold. The tailings pit facility was assigned to the Ontario Research Foundation on completion of the Canada Wide Mines Limited campaigns.

Since no tailings slurries were added to the bed after Phase I of the CANMET program, the water balance altered. This resulted in the implementation of a new set of environmental parameters which would be equivalent to the five-fold acceleration of Northern Saskatchewan weathering conditions.

3.2.3 Design Parameters for the Canada Wide Mines Limited Tailings Pit

Knight and Piesold designed the tailings facility for the Canada Wide Mines Limited Pilot Plant runs based on the following parameters:

Total tailings production planned	26 tonnes dry,
Assumed final dry density of tailings	0.9 t/m^3,
Average rate of ore treatment	22.67 kg/hr (50 lbs/hr),
Average rate of tailings production	29.48 kg/hr (65 lbs/hr),
Average rate of water input into facility	0.058 m^3/hr,
Average rate of slurry input into facility	0.079 m^3/hr.

The above rates of tailings production were initially anticipated for a period of 7 days (24 hours per day). Based on these parameters, Knight and Piesold derived the design requirements for the construction of Canada Wide Mines tailings pit facility at the Ontario Research Foundation with respect to the required surface area, deposition, cycle time, etc.

3.2.4 Construction Details

The overall layout of the proposed tailings facility is shown in Figure 3.1. The principal features prescribed by Knight and Piesold for this facility were:

- a graded (about 1.7% slope) filter blanket with underdrain over the entire base to collect vertical seepage from the tailings;
- a sloping pervious zone at the downstream end, also with internal drainage, to collect supernatant water from the tailings and surface runoff. The tailings were to be discharged at the end remote from the sloping pervious zone in thin layers to simulate subaerial deposition;

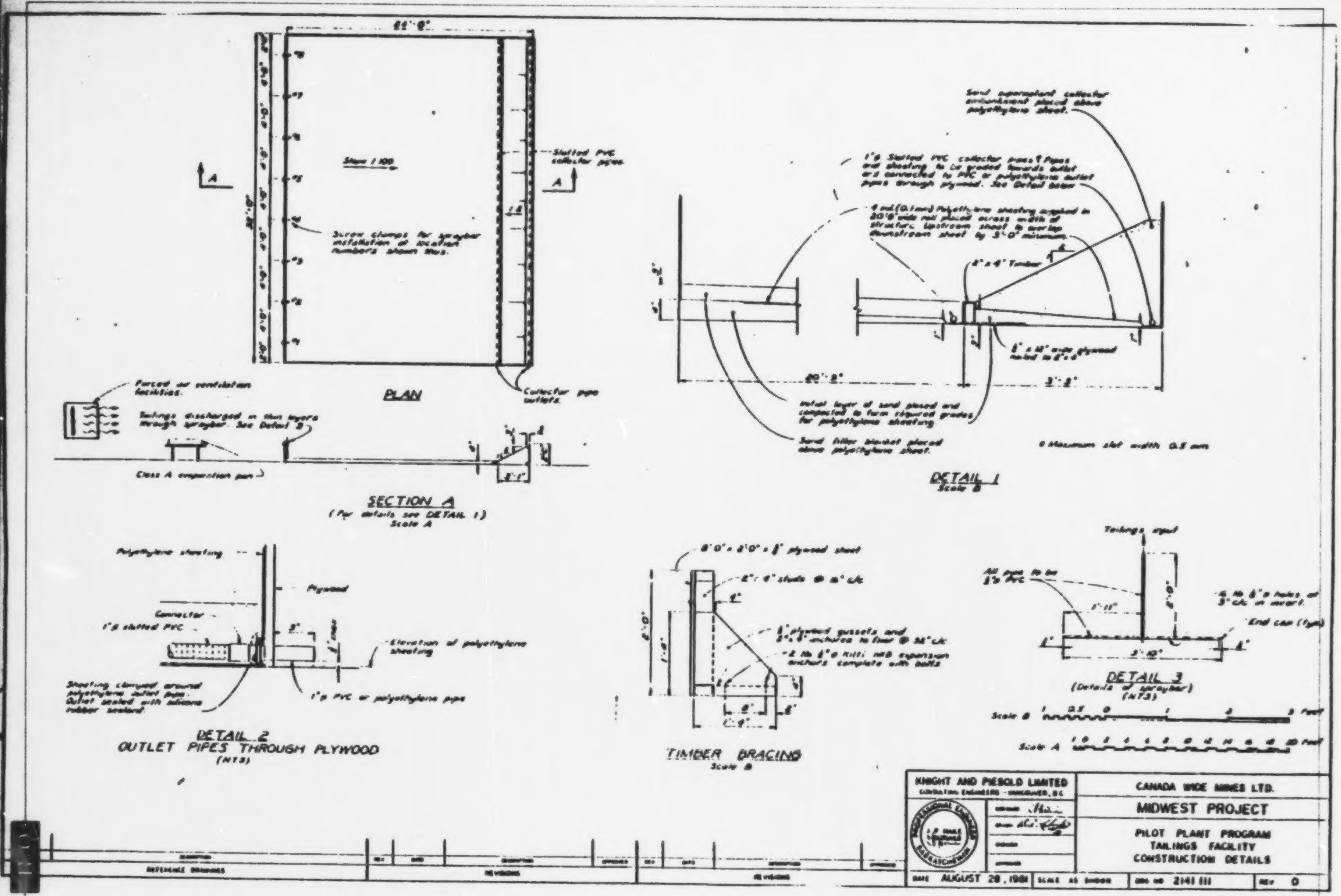
22'-0"
20'-0"
Slotted PVC collector pipes.
A
Screw clamps for spraybar installation at location numbers shown thus.
Collector pipe outlets.
PLAN
Forced air ventilation facilities.
Tailings discharged in thin layers through spraybar. See Detail 3
Class A evaporation pan
2'-1"
SECTION A
(For details see DETAIL 1)
Scale A
Sand supernatant collector embankment placed above polyethylene sheet.
1"ø Slotted PVC collector pipes.* Pipes and sheeting to be graded towards outlet and connected to PVC or polyethylene outlet pipes through plywood. See Detail below
4 mil (0.1mm) Polyethylene sheeting supplied in 20'0" wide roll placed across width of structure. Upstream sheet to overlap downstream sheet by 3'-0" minimum.
2" x 4" Timber
½" x 12" wide plywood nailed to 2" x 4"
20'-2"
3'-8"
Initial layer of sand placed and compacted to form required grades for polyethylene sheeting
Sand filter blanket placed above polyethylene sheet.
* Maximum slot width 0.5 mm
DETAIL 1
Scale B
Polyethylene sheeting
Plywood
Connector
1"ø slotted PVC
3"
Elevation of polyethylene sheeting
Sheeting clamped around polyethylene outlet pipe. Outlet sealed with silicone rubber sealant.
1"ø PVC or polyethylene pipe
DETAIL 2
OUTLET PIPES THROUGH PLYWOOD
(NTS)
8'0" x 2'0" x ½" plywood sheet
2" x 4" studs @ 16" c/c
½" plywood gussets and 2" x 4" anchored to floor @ 32" c/c
2 No ½"ø Hilti HKB expansion anchors complete with bolts
2'-0"
1'-8"
8"
1'-4"
TIMBER BRACING
Scale B
Tailings input
All pipe to be 1½"ø PVC
1'-11"
2'-0"
16 No ⅛"ø holes at 3" c/c in invert.
End cap (typ)
3'-10"
DETAIL 3
(Details of spraybar)
(NTS)
Scale B 1 0.5 0 1 2 3 Feet
Scale A 1 0 2 4 6 8 10 12 14 16 18 20 Feet
KNIGHT AND PIESOLD LIMITED
CONSULTING ENGINEERS · VANCOUVER, B.C.
CANADA WIDE MINES LTD.
MIDWEST PROJECT
PILOT PLANT PROGRAM
TAILINGS FACILITY
CONSTRUCTION DETAILS
DATE AUGUST 28, 1981
SCALE AS SHOWN
DWG NO 2141 111
REV 0
REFERENCE DRAWINGS
REVISIONS

Figure 3.1

- plan dimension of 71.3 m^2 (24 x 32 ft.) confined by a 60 cm (2 ft.) high plywood wall supported by 4.9 cm x 9.8 cm (2 x 4") studs and plates, with bracing and anchoring to the floor on every second stud;

- water tightness of the timber framing achieved by 0.1 mm (4 mil) polyethylene sheet lining the entire facility area;

- a particle size distribution of the sand in the filter blanket and sloping pervious zone lying within the following limits:

  $0.18 \text{ mm} < D_{50} \text{ sand} < 0.87 \text{ mm},$
  $0.12 \text{ mm} < D_{15} \text{ sand} < 0.40 \text{ mm},$
  $0.075 \text{ mm} < D_5 \text{ sand}.$

These specifications are U.S.B.R. filter criteria required to prevent migration of fines into the sand. This grade suited the anticipated viscosity of the tailings material;

- drainage outlets within the filter blanket and pervious zone provided in the form of slotted PVC pipes leading to a sealed outlet through the polyethylene liner and plywood surround. Free discharge from these pipes was provided either by leading the outlets to sumps before recycling, or by direct pumping. A build-up of free water must not be allowed to occur in the outlet pipes.

3.2.5 Operating Procedure

3.2.5.1 Tailings Deposition

During deposition, the tailings material was:

- distributed into the facility through a spray bar at the upstream;
- pumped through a spray bar 30 cm long with holes at uniform spacing along its length;
- moved down the slope of the filter blanket by laminar flow;
- deposited through the spray bar to eight positions along the length of feed side on a rotational basis;
- deposited for approximately 12 hours to build up a layer of the filter blanket at one position. Thereafter the spray bar was relocated to the next position. Later spreading of each layer was anticipated during the initial stages;
- had a cycle time of 4 days, with eight spray bar relocations at 12-hour invervals before the discharge position was returned to cover a previously emplaced layer.

3.2.5.2 Monitoring Procedures

Systematic records of the following variables were kept to enable a full evaluation to be made on the completion of a campaign.

Slurry Input Data

(i) Total slurry input
(ii) Solids content of slurry
(iii) Weight of tailings solids input
(iv) Volume of water in slurry input
(v) Location of spray bar

Atmospheric Data

(vi) Pan evaporation rate
(vii) Volume of water addition for rainfall simulation

Water Recovery

(viii) Volume of water recovered in filter blanket
(ix) Volume of water recovered in supernatant collector system
(x) Sampling of both water recovery systems for water quality

Additional testing was carried out on a periodic basis as follows:

(i) Moisture content sampling of the tailings layers;
(ii) Radon flux measurements of the tailings;
(iii) Density determination on the consolidated tailings layers.

After completion of their campaigns, Canada Wide Mines Limited in consultation with Knight and Piesold were able to obtain accurate estimates of the average daily water balance and supplementary information regarding the slurry characteristics and tailings characteristics after deposition.

3.3 Actual Construction Details of the Tailings Pit at O.R.F.

The inside containment dimension was 6.1 x 6.1 m. It was necessary to clear and level a floor space of 7.9 m x 7.9 m to accommodate the structure complete with timber bracing.

The facility was confined by a 1.2 m high, 1.9 cm thick plywood wall supported by 5 cm x 10 cm studs and plates. Bracing studs were located every 0.6 m. These were securely fastened to the concrete floor by two 1.25 cm diameter anchor bolts. Additional 5 cm x 10 cm studs were spaced at 0.3 m centres between braced studs.

Water tightness of the timber containment structure was achieved by 10 mil polyethylene sheet lining all internal surfaces. Concrete sand was spread in accordance with the design drawings.

Drainage outlets within the sand filter blanket were installed in the form of 2.54 cm diameter, slotted PVC pipe leading to a sealed outlet through the polyethylene liner and plywood wall. Tailings distribution spray bars were constructed from 1.3 cm diameter PVC pipe with 0.3 cm diameter holes at 7.65 cm centres. All plywood joints and pipe penetrations were sealed with silicon caulking.

The particle size distribution of the sand used in the base of the lysimeter is presented in Table 3.1.

TABLE 3.1
PARTICLE SIZE DISTRIBUTION OF THE LYSIMETER SAND BASE

Size		Weight	
Mesh	Microns	% Retained	Cumulative % Passing
20	841	60.0	40.0
28	595	26.0	14.0
48	297	6.0	8.0
65	210	1.8	6.2
80	177	2.2	4.0
100	149	1.0	3.0
200	74	1.3	1.7
-200	-74	1.7	

The 8 x 8 m pond area was enclosed by polyethylene and dry wall. The ceiling of the enclosure was 2.5 m high. Ventilation of the facility was provided through a single 0.33 m diameter pipe with a 45 m^3/min. exhaust fan.

A 220,000 Btu/hr. capacity propane burner was used for additional heat input. To create air turbulence over the tailings area, a fan with air flow directed down towards the tailings surface was installed on each corner of the tailings enclosure.

Evaporation pans with a 0.064 m^2 surface area were installed in four locations (centre of each side of the enclosure) at 1.4 m above ground level.

The tailings stream was pumped from the neutralization circuit by a 3.8 cm Sala slurry pump and discharged through a 1.27 cm line and spray T-bar to one of five discharge points located along the feed side of the pond.

Because of relatively low slurry volume, it discharged mostly under gravity flow conditions, at best dividing into two streams through the perforated T-bar.

The seepage and runoff pipes were connected individually to Masterflex peristaltic pumps that operated continuously. Each discharged to a separate graduated 120L surge tank. In addition to periodic flow measurements, the total volume collected in the surge tanks was recorded before transferring it to a common tank as feed to the Ra-As precipitation circuit.

The installation, start-up and operation of the tailings pond was supervised by representatives of Knight and Piesold Limited (Messrs. J. Haile and H. Dew). Canada Wide Mines Limited used this facility for two campaigns before O.R.F. took over the tailings pit for conducting the CANMET program.

Knight and Piesold plans used for the construction of the tailings facility are shown in Figure 3.1

3.4 Tailings Disposal Aspects of Canada Wide Mines Limited Campaigns 1 and 2

3.4.1 General

Canada Wide Mines Limited carried out two pilot plant campaigns (Campaign 1 between November 25 and December 17, 1981, and Campaign 2 between January 25 and February 5, 1982) at Ontario Research Foundation.

Due to operational difficulties experienced upstream from the tailings storage facility, only data from the final 5 days of the first campaign (viz. between December 12 and 17, 1981) were analysed. By the second campaign, all of the operational difficulties had been overcome enabling collection of data for the complete duration of the campaign.

3.4.2 Method of Tailings Deposition During C.W.M.L. Campaigns 1 and 2

Tailings were pumped on a near continuous basis from the tailings neutralization circuit to the spray bar located at different positions at the upstream end of the tailings facility. Tailings flowed out of the spray bar and over the sand filter blanket for the first cycle, producing a uniform laminar material flow down the slope of the filter blanket and allowing a build-up of a tailings layer up to 100 mm thick over the length of the blanket. After approximately 12 hours of discharge in one location, the spray bar was moved to the adjacent position. In approximately 60 hours a full cycle was completed and the spray bar was then returned to its initial location for the commencement of a second cycle.

Because of wide fluctuations in the pumping rate, non-homogeneity of the tailings slurry and difficulty in modelling and operating of the spray bars at such relatively small flows, considerable variation took place in the mode of tailings deposition, and steady laminar flow was seldom achieved.

3.4.3 Method of Water Recovery From The Tailings Pit During C.W.M.L. Campaigns 1 and 2

Water in the tailings slurry and from the simulated precipitation applied independently to the tailings was recovered by gravity drainage into two independent drainage systems; one to collect vertical drainage through the tailings and the second to collect surface runoff. These systems allowed both recovery rates and volumes to be determined. Water draining by gravity through the tailings or around the edges of the facility was collected in the sand filter blanket and reported as seepage.

Water bleeding to the surface from freshly deposited tailings, together with the surface runoff of added rainfall, was collected in the sand embankment and reported as supernatant runoff. Owing to pump failures and to insufficient pump capacity, some supernatant runoff was at times able to pond on the downstream edge of the tailings beach, increasing the proportion of water collected as seepage.

3.4.4 Experimental Rainfall Events

Following the completion of Campaign No. 2, the bed was allowed to dry and consolidate for approximately 8 days. A partial closedown of the evaporation system during this time resulted in relatively slow drying and consolidation of the tailings. Simulated rainfall events were then applied to the tailings surface to monitor infiltration and surface runoff.

Prior to the addition of the rainfall, the moisture content of the bed was determined at three locations equidistant down the centre of the facility. The edges of the tailings bed were raised slightly, and cracks reaching the edge of the facility were plugged to prevent runoff water from flowing directly into the sand filter blanket and thus into the seepage reservoir. In order to allow free drainage of runoff through the embankment and into the runoff collection reservoir, the downstream sand embankment was cleared of any crystallized material, precipitate and settled solids that had been generated as the tailings bed dried and consolidated.

After the application of a simulated 500 litres of rainfall, the seepage and runoff quantities were monitored. The moisture content of the tailings bed was determined at locations close to those of previous samples. A total of three rainfall events were initiated at approximately 24-hour intervals, and 3 or 4 readings of moisture content within the bed were made between each application.

3.4.5 Monitoring of the Tailings Pit During C.W.M.L. Campaigns 1 and 2

Monitoring of the facility was carried out on a day-to-day basis by O.R.F. personnel under the supervision of Knight and Piesold Limited personnel.

The following data were kept on a regular basis by O.R.F.:

(i) Slurry input rate;
(ii) Solids content of slurry
(iii) Weight of tailings input (average);
(iv) Volume of water in slurry input (average);
(v) Location of spray bar;
(vi) Pan evaporation;
(vii) Volume of water addition for rainfall simulation;
(viii) Room temperature;
(xi) Volume of water recovered from the filter blanket (seepage);
(x) Volume of water recovered in the supernatant collection system (runoff);
(xi) Sampling of tailings slurry and ambient air as required for mass balance and environmental considerations.

Testing carried out by Knight and Piesold Limited personnel included:

(i) Sampling of tailings layers to determine moisture content;
(ii) Measurement of the radon flux from the tailings surface;
(iii) Assessment of rainfall distribution when applied to the drying tailings bed;
(iv) Density and permeability determinations on undisturbed samples of consolidated tailings;
(v) Particle size distribution within the bed.

Details of the actual test methods used are given in Appendix A.

3.4.6 Chemistry of the Feed to the Tailings Pond

The operational details of the C.W.M.L. campaigns is the proprietary information of Canada Wide Mines Limited. An averaged analysis of the feed to the tailings pit is given below.

Solids	U:	0.25%	Liquid	U:	<0.5 ppm
	As:	2.0%		As:	6 ppm
	Ni:	1.2%		Ni:	1 ppm
	T^{226}Ra:	3500 pCi/g		T^{226}Ra:	10 pCi/L

These figures include analyses of feed which passed through the plant before it was fully operational.

3.4.7 Summary of the Knight and Piesold Results

Knight and Piesold submitted a detailed report on the deposition and testing of the layered tailings bed to C.W.M.L. That report has been used to obtain a more complete picture of the performance of the pit during the initial phases of the project. A summary of the Knight and Piesold data is given in Appendix A.

The pilot plant facility satisfactorily demonstrated many of the features of sub-aerial deposition, principally during the early phases of operation of the prototype facility. Total water recoveries from the incoming tailings, with added precipitation were in the 40% to 45% range and confirmed previously established design data. As the thickness of deposited tailings was increased, the expected trend of larger runoff quantities and a levelling of seepage quantities were developed. Precipitation recovery was approximately 90% in runoff and 10% in seepage.

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A larger quantity of water than expected was retained in the tailings mass, largely as a result of higher than design quantities of incoming water, short cycle times between layer deposition and the consequent inability of the evaporation regime, as maintained, to remove this excess water. As a result, the dry densities and moisture contents observed in undisturbed samples did not attain expected values.

Dry density of the tailings after consolidation to confining pressures of 200 kPa was also lower than predicted by Knight and Piesold. This may be attributable to a variation in material characteristics.

Heterogeneity of the tailings bed is shown by variations in depth of permeability, grain size distribution, moisture content and Atterberg limits.

The radon flux of the bed increased as the moisture content of the bed was decreased.

No studies were conducted on the distribution of radionuclides within the tailings bed, seepage or runoff waters.

4. THE CANMET PILOT PLANT CAMPAIGN

4.1 Introduction

A total of 2.7 tons of Midwest (Saskatchewan) uranium ore was treated as part of Phase I of the CANMET pilot plant tailings project (DSS Contract OSQ-81-00211) during the period March 22 - 31, 1982.

The initial 6 of 24 feed batches treated included, at the request of Canada Wide Mines Limited, ore from Canada Wide Mines Limited pilot plant blending 1800 kg of waste and special waste (dry basis) stored at O.R.F. with 320 and 290 kg of high (13.8% U) grade Midwest ore shipped from storage at Lakefield Research of Canada Limited.

Some repairs and reconditioning of motors, pumps, agitators, control equipment, feed lines, and process vessels were required before the start-up of the 8-day operation.

4.2 Pilot Plant Flowsheet

The pilot plant unit operations included grinding, leaching, counter-current decantation, clarification, solvent extraction, yellowcake precipitation, raffinate and tailings neutralization, radium-arsenic precipitation and tailings deposition in the Knight and Piesold layered tailings storage facility. The flowsheets are shown in Figures 4.1 and 4.2.

A brief outline of the operation is discussed below. Sampling instructions and chemical analysis of various process stream samples collected during the pilot plant run are shown in Appendix B. The weights of yellowcake produced are shown in Appendix C.

4.3 Grinding and Neutral Thickening

The feed was ground to 30% minus 74 micron size using a 0.6 m dia. x 0.2 m Hardinge ball mill in closed circuit with a 700 micron opening DSM screen. The screen undersize discharged, with the addition of Percol 351 flocculant, to a 0.9 m diameter neutral thickener. The thickener overflow was recirculated to dilute the screen feed, while the underflow was withdrawn to accumulate a batch of leach feed.

FIGURE 4.1

Schematic Diagram of Uranium Mill Tailings Generation and Disposal System

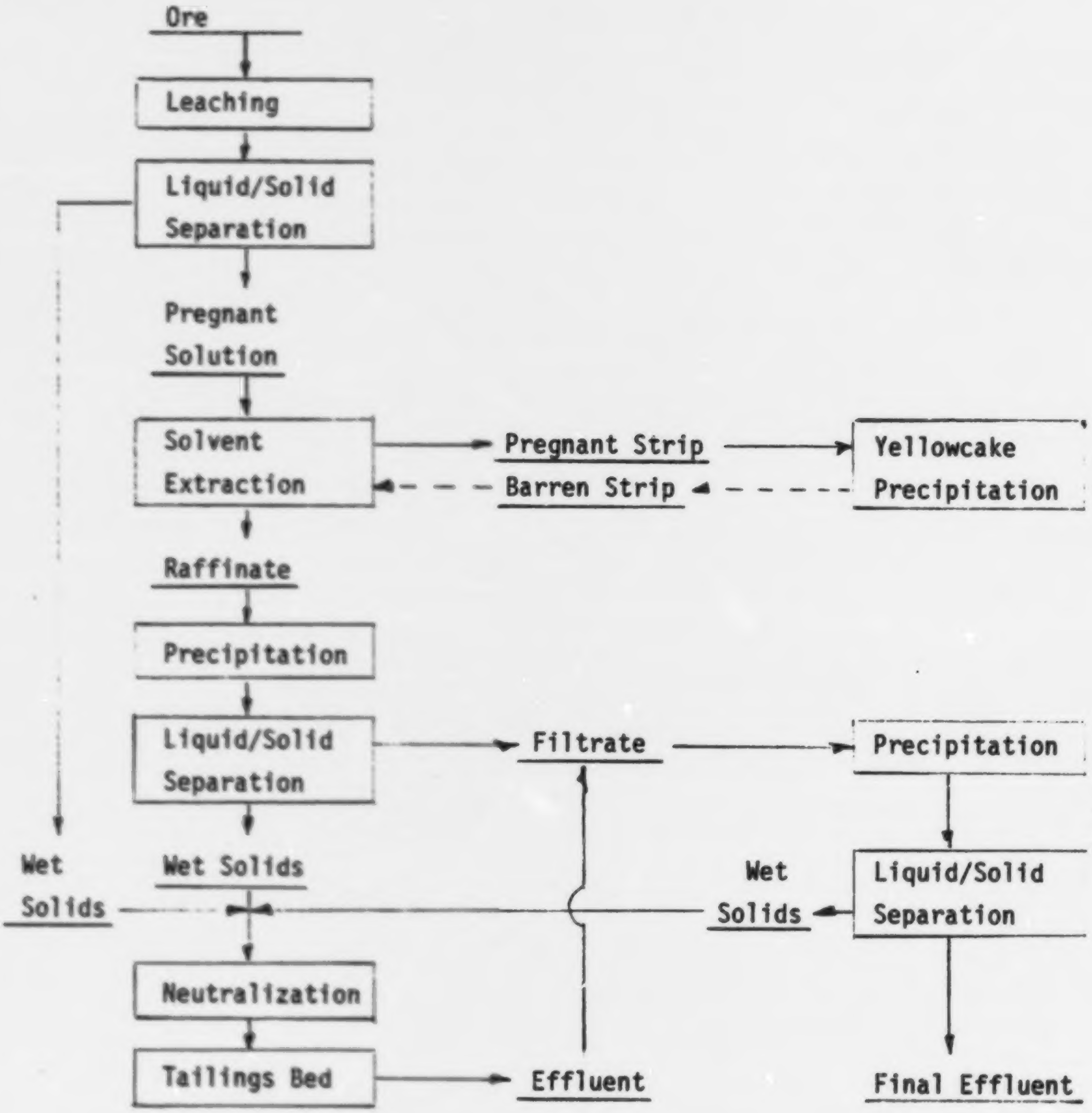

Ore
Leaching
Liquid/Solid Separation
Pregnant Solution
Solvent Extraction
Pregnant Strip
Barren Strip
Yellowcake Precipitation
Raffinate
Precipitation
Liquid/Solid Separation
Filtrate
Precipitation
Wet Solids
Wet Solids
Liquid/Solid Separation
Wet Solids
Neutralization
Tailings Bed
Effluent
Final Effluent

FIGURE 4.2

Pilot Plant Flow Sheet

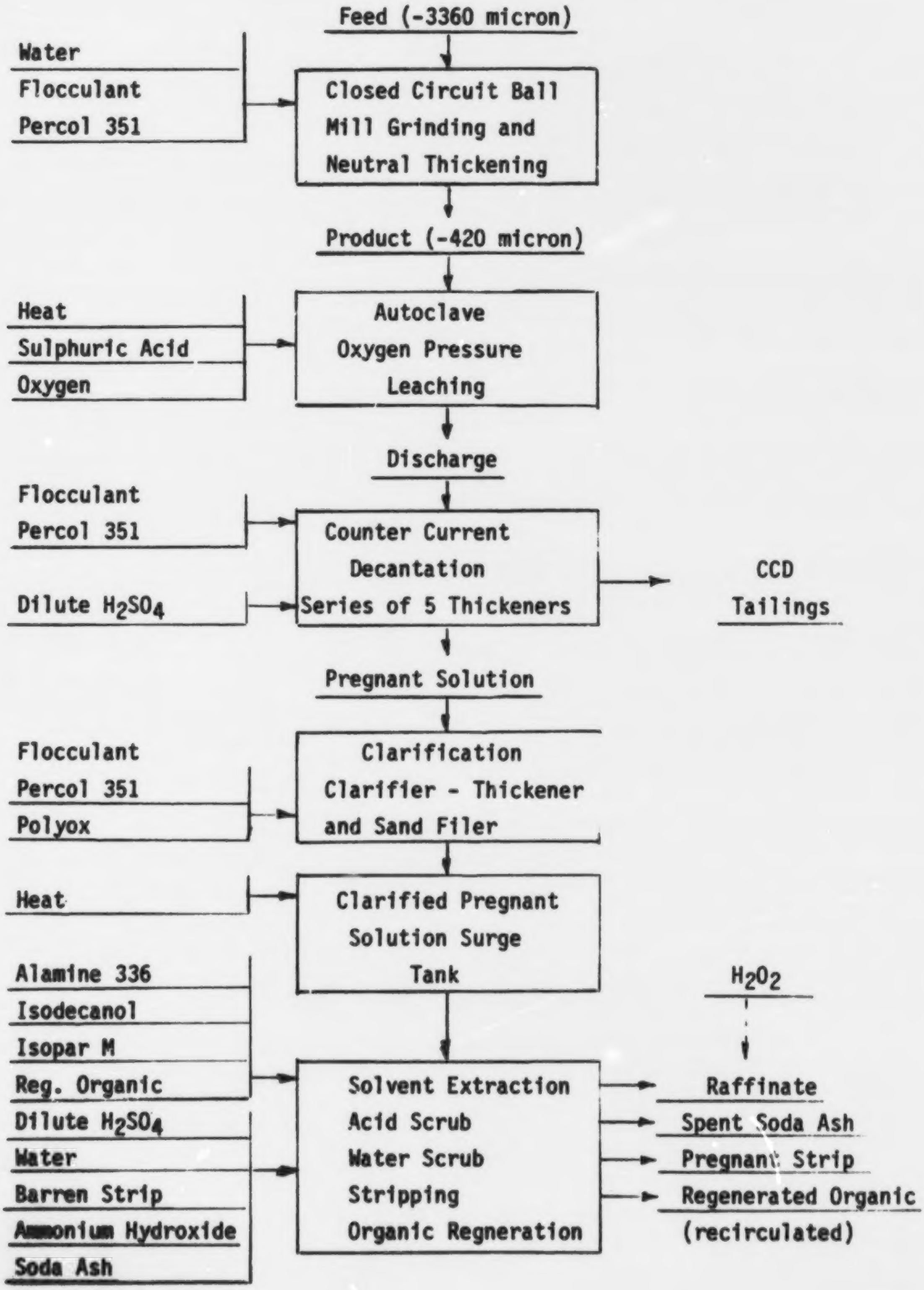

Feed (-3360 micron)
Water
Flocculant
Percol 351
Closed Circuit Ball Mill Grinding and Neutral Thickening
Product (-420 micron)
Heat
Sulphuric Acid
Oxygen
Autoclave Oxygen Pressure Leaching
Discharge
Flocculant
Percol 351
Dilute H_2SO_4
Counter Current Decantation Series of 5 Thickeners
CCD Tailings
Pregnant Solution
Flocculant
Percol 351
Polyox
Clarification Clarifier - Thickener and Sand Filer
Heat
Clarified Pregnant Solution Surge Tank
Alamine 336
Isodecanol
Isopar M
Reg. Organic
Dilute H_2SO_4
Water
Barren Strip
Ammonium Hydroxide
Soda Ash
Solvent Extraction
Acid Scrub
Water Scrub
Stripping
Organic Regneration
H_2O_2
Raffinate
Spent Soda Ash
Pregnant Strip
Regenerated Organic (recirculated)

FIGURE 4.2 (cont'd.)

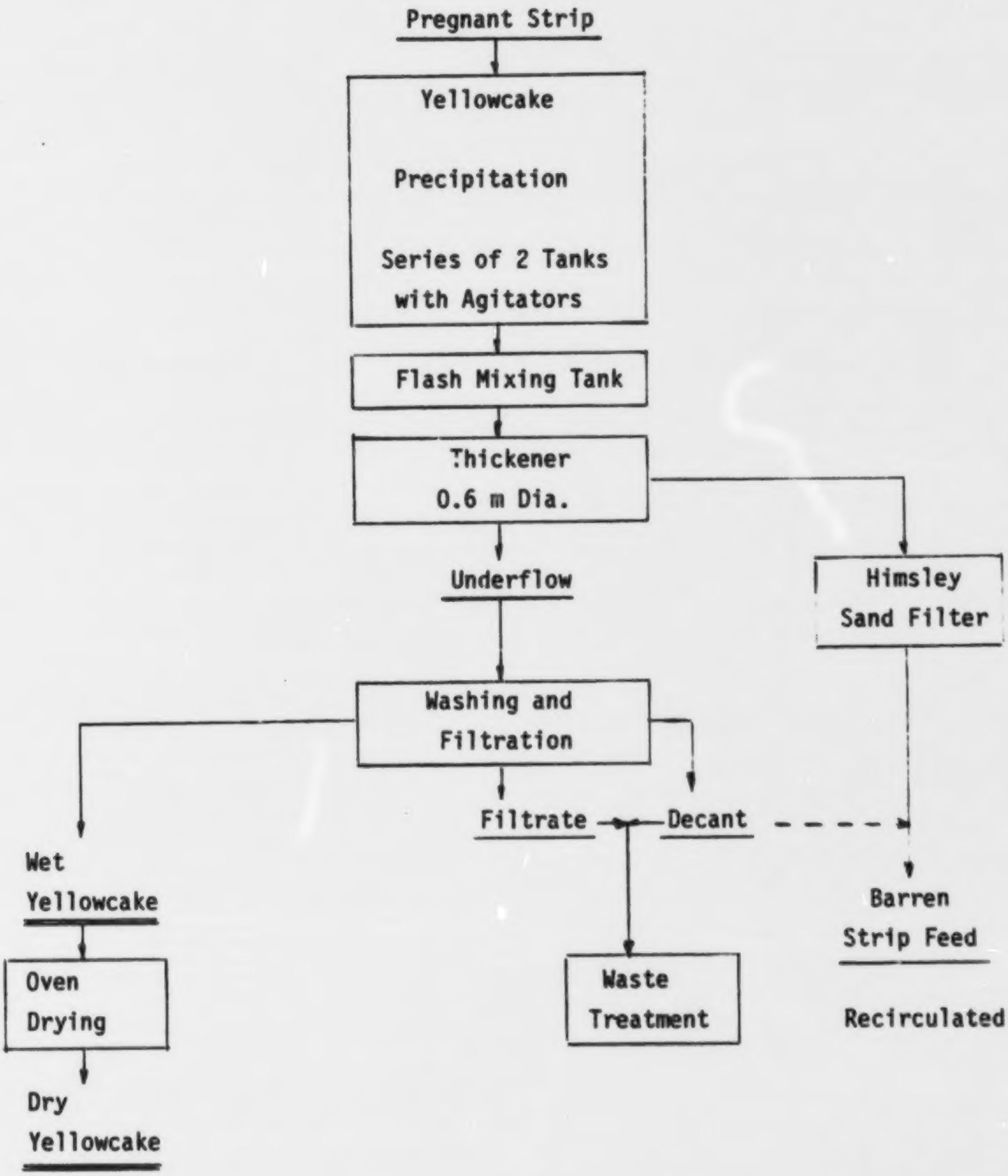
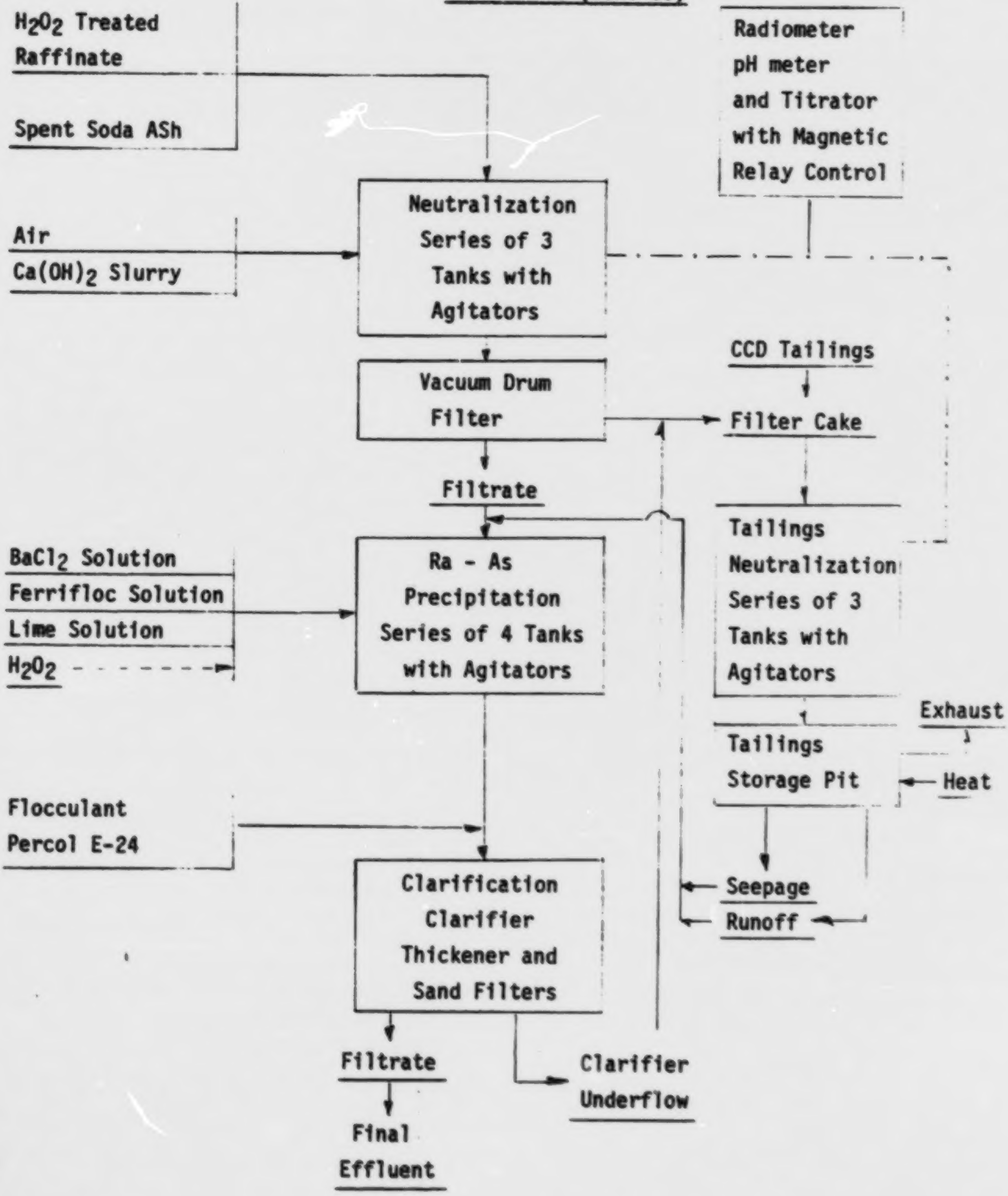

Pregnant Strip
Yellowcake
Precipitation
Series of 2 Tanks
with Agitators
Flash Mixing Tank
Thickener
0.6 m Dia.
Underflow
Himsley
Sand Filter
Washing and
Filtration
Filtrate
Decant
Wet
Yellowcake
Oven
Drying
Dry
Yellowcake
Waste
Treatment
Barren
Strip Feed
Recirculated

FIGURE 4.2 (cont'd.)


H_2O_2 Treated Raffinate
Spent Soda ASh
Radiometer pH meter and Titrator with Magnetic Relay Control
Neutralization Series of 3 Tanks with Agitators
Air
$Ca(OH)_2$ Slurry
CCD Tailings
Vacuum Drum Filter
Filter Cake
Filtrate
Tailings Neutralization Series of 3 Tanks with Agitators
$BaCl_2$ Solution
Ferrifloc Solution
Lime Solution
H_2O_2
Ra - As Precipitation Series of 4 Tanks with Agitators
Exhaust
Tailings Storage Pit
Heat
Flocculant Percol E-24
Seepage
Runoff
Clarification Clarifier Thickener and Sand Filters
Filtrate
Final Effluent
Clarifier Underflow

4.4 Leaching

Leaching of the ground pulp was carried out in a 210 L Pfaudler autoclave under acid pressure leach conditions.

4.5 Counter-Current Decantation

Liquid/solid separation and washing of the leached product was carried out in a series of five 0.9 m diameter Dorr thickeners. Percol 351 was used as a settling aid and dilute sulphuric acid was used for washing.

The first thirteen and the last eleven batches were processed at different flowrates, as shown in Table 4.1.

TABLE 4.1

C.C.D. OPERATING DATA

Batch Nos.		1 - 13	14 - 24
Feed Flowrate	L/min.	0.32	0.43
Tailings Flowrate	L/min.	0.49	0.63
Pregnant Solution Flow	L/min.	0.96	1.13

4.6 Clarification of Pregnant Solution

The pregnant solution from the liquid/solid separation circuit was clarified in a 0.6 m diameter clarifier-thickener and a 15 cm dia. x 150 cm Himsley sand filter. Percol 351 flocculant was added to the clarifier feed. Also, additions of Polyox were made to determine its effect on emulsion control in subsequent solvent extraction.

4.7 Solvent Extraction

The solvent extraction circuit included four extraction mixer-settlers, two acid scrub, one water scrub, five strip and one organic regeneration mixer-settler, and two after settlers.

The clarified pregnant feed temperature was maintained between 32°C and 35°C by a floating immersion heater installed in the 500 L clarified feed surge tank.

The average flowrates of the solvent extraction circuit are shown in Table 4.2.

TABLE 4.2
AVERAGE SOLVENT EXTRACTION FLOWRATES

Input	Average mL/min.
Extraction	
Clarified pregnant feed	1035
Regenerated organic	1025
Scrubbing	
Dilute H_2SO_4 solution	47
Water	59
Stripping	
Barren strip	260
Ammonium hydroxide	10
Regeneration	
Soda ash solution	78
Output	
Raffinate	1140
Pregnant strip liquor	270
Spent soda ash	77
Regenerated organic	1010

4.8 Raffinate Neutralization and Radium/Arsenic Precipitation

Average flowrates in the waste solution treatment circuit are shown in Table 4.3.

TABLE 4.3

RAFFINATE TREATMENT AND RADIUM/ARSENIC PRECIPITATION CIRCUIT FLOWRATES

		mL/min.
Raffinate and spent soda ash		1217
Calcium hydroxide addition as a 15% slurry		266
Hydrogen peroxide addition (to raffinate circuit feed)		13
Drum filter cake (gypsum)		
Total wet cake	1903 kg	
Total dry cake	628 kg	
Drum filter filtrate to Ra-As precipitation		1312
Drum filter filtrate to tailings		33
Tailings seepage and runoff		179
Ra-As precipitation circuit feed		1491
H_2O_2 addition (to Ra-As precipitation circuit feed)		7
$BaCl_2$ addition		6
Ferrifloc addition		27
Percol E-24 addition		5
Ra-As clarifier overflow		1307

The raffinate neutralization and radium/arsenic precipitation produced environmentally acceptable levels of radium and arsenic in effluent during the CANMET campaign. During earlier campaigns of Canada Wide Mines Limited, the molybdenum level was above the environmentally acceptable limit. Bench scale tests were carried out during the CANMET campaign to correct this. It was found that hydrogen peroxide additions to the neutralized raffinate and tailings effluent could occasionally reduce the molybdenum level to below 0.5 ppm in the final effluent. Detailed test work would be required to optimize this process.

The treatment of the tailings prior to feeding into the tailings pit is dealt with in Section 5.2.1.

5. THE CANMET TAILINGS PROGRAM

5.1 General

The tailings produced during the pilot plant run were treated and fed into the tailings facility. Sampling during the CANMET tailings program was planned as follows:

CANMET PHASE I:
- solids feed to the tailings facility
- liquid feed to the tailings facility
- tailings runoff/tailings seepage
- air above the tailings bed
- four core samples at the completion of Phase I.

This part of the study provided data on the quality of the tailings effluent during mill run conditions.

CANMET PHASE II:
- weekly composite samples as in Phase I
- four core samples of tailings upon completion of Phase II.

This phase is divided into 2 parts: during Phase II - Part 1 Northern Saskatchewan climate conditions were being set up, and during Phase II - Part 2, Northern Saskatchewan conditions were achieved. This phase provides data representative of mill shutdown conditions.

CANMET PHASE III
- weekly samples for eight weeks and monthly samples thereafter of tailings runoff and seepage, and samples of the air above the tailings bed

- four core samples of the tailings after four months in Phase III and again upon the completion of Phase III.

This part of the study provided data under simulated Northern Saskatchewan climatic conditions on a tailings facility representative of conditions of abandonment.

CANMET PHASE IV:
- monthly composite samples of seepage and runoff and of the air above the tailings, for analysis
- four core samples of the tailings at the completion of Phase IV - Part 1 and a further four core samples at the completion of Phase IV-Part 2. Concurrently with this sampling, a core was also extracted from a section of the bed subjected to freezing-thawing.

Phase IV of the program was conducted under similar climatic conditions as Phase III but rainfall pH was adjusted to about 5.4. A section of the tailings bed was isolated and subjected to freeze-thaw testing to a depth of 40 cm. Prior to the Part 1 core sampling, the tailings were subjected to accelerated flooding conditions, equivalent to 1:25 year flooding in Northern Saskatchewan.

5.2 CANMET Tailings Phase I

5.2.1 Preparation of the Tailings Feed to the Tailings Facility

The feed to the tailings neutralization circuit included solids discharged from No. 5 thickener, and solids precipitated in the raffinate neutralization and radium/arsenic precipitation circuits. The slurry was neutralized to pH 11 by the addition of 15% calcium hydroxide slurry, and discharged to the tailings pond. The neutralized tailings flow rate averaged 0.72 L/min. and contained 32.6% solids. The viscosity of the neutralized tailings, containing 22% and 34% solids respectively, was measured at 7°C in a Fann viscometer at shear rates varying from 0.8 to 1022 S^{-1}.

The functional relationship between shear stress rate was non-linear, indicating that the neutralized tailings slurry was a pseudo-plastic fluid. This may explain why the slope of the test facility surface was >1%, whereas 1% was predicted by Knight and Piesold in design criteria. The viscosity, which reflects other physical properties of the feed, probably influences the angle of repose of the particles and thus the slope obtained.

5.2.2 Deposition of the Tailings - CANMET PHASE I

The tailings from the CANMET pilot plant program were deposited in the tailings pond between March 22 and 31, 1982. They were deposited over a base consisting of tailings produced during the Canada Wide Mines Limited Campaigns 1 and 2 which were emplaced under the supervision of Knight and Piesold. Details of the characteristics of the tailings pit after the deposition of the Canada Wide Mines Limited Campaigns 1 and 2 tailings, based on a report written by Knight and Piesold, are given in Appendix A.

Spraying of the tailings into the tailings pit during the CANMET program took 161 hours during the 8-day run. Rain (2550 L)* was sprayed onto the tailings pit surface for ten minutes by hose each day during the tailings deposition. The deposition of the first layer of CANMET tailings took 67 hours during which time the spray bar was systematically moved across the width of the tailings pit in nine equal distance increments. Varying periods of time (25, 17, 8, 12 and 4 hours sequentially per layer, followed by periods of less than 1 hour at depressions) were spent distributing the balance of the material. This was done to create a uniform runoff during artificial rainfall events occurring during the subsequent phases of the CANMET study. As with the Knight and Piesold/C.W.M.L. campaigns, true laminar flow was not always achieved during the deposition of the tailings.

* This figure was prescribed by Knight and Piesold and is based upon Northern Saskatchewan hydrometeorological data - Refer Appendix D.

5.2.3 Chemistry of the Feed to the Tailings Facility during the CANMET (Phase I) Pilot Plant Campaign

The neutralized tailings (including ore which passed through the plant before it was fully operational) fed into the tailings facility had an average analysis as shown in Table 5.1.

TABLE 5.1

COMPOSITION OF THE NEUTRALIZED TAILINGS FEED

Feed Material	Quantity	Uranium	Radium	Arsenic	Nickel
Solids	3348 kg	0.25%	4573 pCi/g	2.27%	1.44%
Liquids	7318 L	0.0002 gpL	10 pCi/L	0.0004 gpL	0.0002 gpL

The low levels of uranium, radium-226, arsenic and nickel in the neutralized tailings liquid indicate that the neutralization of the tailings was successful, much of the deleterious elements having been precipitated as solid phases.

The neutralized tailings fed into the tailings facility consisted of a blend of raffinate neutralization filter cake, filtrate, CCD underflow, a radium-arsenic precipitate produced from clarifier underflow material, and a calcium hydroxide slurry. The proportions of these materials are shown in Table 5.2.

TABLE 5.2

CHARACTERISTICS OF THE NEUTRALIZATION TAILINGS FED TO THE TAILINGS BED

Material	Pulp Weight (kg)	Pulp Density % Solids	Proportion Solids:Liquid
CCD Tailings	7176	35.4	2540:4636
Raffinate Neutralization Filter Cake	1903	33.0	628:1275
Filtrate (for pulp dilution)	337	-	0: 337
Radium Arsenic Precipitate Produced from Clarifier Underflow	90	6.7	6: 84
Calcium Hydroxide Slurry	1160	15.0	174: 986

The calcium hydroxide slurry contained no U, As, or Ni. It was not analyzed for Ra-226. The weight percentage distribution of the U, Ni, As and Ra-226 between the various components of the feed is presented in Table 5.3.

TABLE 5.3
CHEMISTRY OF THE FEED TO THE TAILINGS FACILITY

Type of Material		Percentage Distribution U	As	Ni	Ra-226**
CCD Tailings:	Solids	78.9	56.8	65.3	N.A.
	Liquid	15.2	1.7	1.8	N.A.
Others*		5.9	41.5	32.9	N.A.
Neutralized Tailings Effluent		0.1	0.1	0.1	N.A.
		100.1	100.1	100.1	

N.A.: Not Available

* Included raffinate neutralization filter cake and pulp dilution filtrate for tailings pulp dilution

** Ra-226 values were only determined on the total solids and liquids fed to the tailings facility and not on the individual constituents.

5.2.4 Material Balance During the Deposition of the Tailings between March 22-31, 1982 (CANMET Phase I)

Details of the quantities of solids and liquids added to the tailings pit during the CANMET Campaign (Phase I) are given in Table 5.4 together with data from the Canada Wide Mines Limited Campaigns 1 and 2.

All of the data pertaining to process details, material balance, etc., are the proprietary information of C.W.M.L. and fall outside the scope of this contract.

TABLE 5.4
COMPARISON OF MATERIAL BALANCES:
CANMET (PHASE 1) & CANADA WIDE MINES LTD.

Parameter		C.W.M.L.* Campaign #1	C.W.M.L. * Campaign #2	CANMET Phase I
Total Solids	-(kg)	2076	3400	3477
Slurry Solids	-(%)	29.1	29.5	32.6
Total Water in Slurry	-(L)	4995	8125	7189
Total Rainfall Added	-(L)	Nil	5500	2550
Runoff Collected	-(L)	390 (8%)	3323 (24%)	1820 (18.6%)
Seepage Collected	-(L)	1750 (35%)	2326 (17%)	945 (9.7%)
Total Water Collected	-(L)	2140 (43%)	5649 (41%)	2765 (28.4%)
Evaporation	-(L)	750 (15%)	2500 (18%)	1308 (13.4%)
Water not Accounted for (Assumed retained in tailings)	-(L)	2105 (42%)	5476 (40%)	4609 (47%)
Water for Resaturation of Tailings Bed	-(L)			1057 (11%)

N.B. All of the above amounts were determined during the deposition of material

* Figures supplied by Knight and Piesold

It can be seen that the slurry density of the feed to the tailings pit was nearly the same during all three campaigns. The decrease in the percentage collected as seepage during the deposition of C.W.M.L. Campaign 2 and subsequent further decrease during the CANMET (Phase I) deposition corresponds to the consolidation of the bed with time, and the greater thickness resulting from deposition.

After Canada Wide Mines Limited Campaign #2, the upper surface of the tailings facility bed dried out. Consequently, 11% of the water fed into the tailings facility during Phase I of the CANMET project was probably required to resaturate the bed onto which the CANMET material was fed. A true picture of the relative proportions of liquid collected as seepage and runoff in the various campaigns can be obtained by examining Table 5.5.

TABLE 5.5
COMPARISON OF RUNOFF AND SEEPAGE
DURING THE C.W.M.L. AND CANMET CAMPAIGNS

		C.W.M.L. Campaign #1	C.W.M.L. Campaign #2	CANMET Phase I
Runoff	(L)	390 (18.2%)	3323 (59%)	1820 (66%)
Seepage	(L)	1750 (81.8%)	2326 (41%)	945 (35%)
Total	(L)	2140 (100.0%)	5649 (100%)	2765 (100%)

It can be seen that as the bed thickness increased, the proportion of the seepage decreased while the proportion of runoff increased.

5.2.5 Plant Effluent, Runoff and Seepage Analyses During Phase I

Phase I simulated conditions which would be encountered in the tailings during mill operating conditions. The analyses of the tailings seepage, tailings runoff and plant effluent are presented in Table 5.6.

TABLE 5.6

PLANT EFFLUENT, RUNOFF AND SEEPAGE ANALYSIS (PHASE I)

Variable		Plant Effluent Liquid	Plant Effluent Solid	Tailings Seepage	Tailings Runoff
Volume liquid	(L)	7318		945	1820
Weight solid	(kg)		3348		
pH				10.6-12.5	6.5-7.4
U	(ppM)	0.2	0.25%		
As	(ppM)	0.4	2.27%	3.6	10.9
Ni	(ppM)	0.2	1.44%	0.07	0.6
Ra-226	(pCi/L)	10	4573 (pCi/g)	10.6	7.3

It can be seen that some reaction has taken place as the pore solution moves through the bed - the pH of the seepage is relatively high as compared with the runoff.

The arsenic content of the runoff is also relatively high.

5.3 Implementation of Northern Saskatchewan Climatic Conditions

Accelerated Northern Saskatchewan summer conditions were initiated on March 31, 1982. This entailed maintaining:

- Northern Saskatchewan summer temperatures. Heater fans and a 200,000 Btu/hr. propane burner were used to heat the facility;
- Northern Saskatchewan evaporation rates;

- implementing alternate cycles of light and darkness (4.8 hour cycle) to simulate day and night. This was achieved by installing an automated system of lights and infrared heaters to simulate sunlight. The facility was enclosed by black polyethylene sheeting to simulate night-time for 2.4 hours of the 4.8 hour cycle, when the heaters were off;

- sprinkling quantities of water onto the tailings bed equivalent to five times the Northern Saskatchewan precipitation for a given period. An hour was allowed for the lamps to cool off before artificial rainfall was applied. The application of the rainfall only took a few minutes during the total 2.4 hour simulated night;

- circulating the air within the tailings facility to minimize areas of localized climate.

Monitoring of the imposed climatic regime entailed recording:

- daily air temperatures (see Appendix E),
- daily volumes of "rainfall, runoff and seepage" (see Appendix F),
- daily evaporation rates (see Appendix F),
- daily variation in tailings bed temperature (see Appendix G).

Emphasis was placed on obtaining the high evaporation rates typical of Northern Saskatchewan. The propane burner was used as required to attain those rates. The average minimum daily temperature was kept at about 18°C and the average maximum daily temperature attained was about 28°C, These temperatures are typical of Northern Saskatchewan summers.

An average of about 160 L of "rainfall" was applied every 24 hours. A comparison of Northern Saskatchewan and attained tailings facility hydrometeorological conditions is shown in Table 5.7

TABLE 5.7

Comparison of Northern Saskatchewan and Attained Tailings Facility Hydro-Meteorological Conditions

Parameter	Northern Saskatchewan	Phase II: Part 1	Phase II: Part 2	Phase III	Phase IV: Part 1 Pre-flooding	Phase IV: Part 1 Post-flooding	Phase IV: Part 2
Mean hours sunshine during summer/24 hr.	12.5 hrs.	One night-day cycle every 4.8 hours					
Main precipitation (Acceleration)	Rainfall: 30.5-40.5 cm (1X)	18 859 L/103 days (ie 183 L/day) (5.9 x min.AR)	2194 L/13 days (ie 169 L/day) (5.4 x min.AR)	40388 L/252 days (ie 160 L/day) 5.2 x min.AR	15,416 L/97 days (5.1 x min.AR) (ie 158 L/day)	10,145 L/4 days (81.6 x min.AR) (2536 L/day)	36,645 L/224 days = 164 L/day 5.3 x min.AR
Mean Total Evaporation (Expressed as a % of rainfall)	24.4 cm - 30 cm (80% - 74%)	(61.5%)	(67%)	(56.5% - 88.5%)	75.4%	45.3%	65%
Date		April 6, 1982 to July 13, 1982	July 13, 1982 to July 26, 1982	July 27, 1982 to April 5, 1983	April 6, 1983 to July 11, 1983	July 12, 1983 to July 15, 1983	October 21, 1983 to May 31, 1984

Note:
1. Min.AR = minimum annual rainfall
2. 37.21 L "rain" applied to pit is equivalent to 1 mm of true rainfall
3. 64 mL evaporate from evaporation pots is equivalent to 1 mm true rainfall

In the simulation, only accelerated summer conditions were imposed. It is assumed that most of the snowmelt will report as runoff. From the table it can be seen that the high evaporation rate typical of Northern Saskatchewan was attained and maintained through Phases II and III. An approximately fivefold acceleration in the amount of rainfall has been maintained. Also, the extremely high evaporation characteristic of Saskatchewan has been achieved. This high evaporation rate is extremely significant because if affects the degree of infiltration of the rainfall. According to Peter S. Eagleson,* "ground-surface evaporation may cause an upward capillary potential gradient which is sufficient to overcome gravity and to move infiltrated water back toward the surface in a process called capillary rise. The delivery of the water to the surface by this mechanism is called exfiltration."

A 30 x 30 cm area of the tailings bed was isolated during the Phase IV campaign, and subjected to alternate freezing and thawing to a depth of 40 cm. Freeze-thaw cycles during Phase IV - Part 1 were as follows:

TABLE 5.8

FREEZE-THAW CYCLES IMPOSED ON THE ISOLATED PORTION OF THE BED

Cycle	Duration	State	Days
1	May 31 - June 5, 1983	Freezing	6
2	June 6 - June 17	Thaw	12
3	June 18 - June 23	Freezing	10
4	June 24 - July 10	Thaw	17
5	July 11 - July 17 (Frozen to 40 cm)	Freezing	7

The temperatures obtained in the freeze-thaw section are contained in Appendix G.

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* "Dynamic Hydrology", McGraw-Hill, 1975

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6. SEEPAGE AND RUNOFF CHARACTERISTICS

6.1 Solution Flows

Daily recordings of the volumes of rain, seepage, runoff and evaporation are provided in Appendix F. Average solution rates, including seepage as a percent of the effluent solution, are presented in Table 6.1 and are illustrated in Figure 6.1.

Factors influencing the quality of water reporting as seepage or runoff include:

- rate of water application,
- rate of evaporation,
- permeability and depth of bed,
- surface cracks or holes.

Over the total period, the proportion of effluent solution (seepage and runoff) appearing as seepage averaged 61%. No significant change in the proportion with time or acidification is evident. Figure 6.2 illustrates the influence of evaporation rate on the proportion of effluent solution appearing as seepage, with high evaporation decreasing the proportion.

The bed was formed attempting to realize the layered bed concept, wherein alternating layers of coarse (high permeability) and fine (low permeability) material encourage runoff at the expense of seepage. In this way, the bulk of the tailings would be removed from the action of rainfall. The effectiveness of the bed in directing the rain to runoff and away from seepage is seen to be rather low. This may be due to the heterogeneity of the tailings bed, discussed earlier. Colour bands seen in core samples have a typical thickness of 10 - 20 mm, and continuity of such bands (assuming they represent strata of varying permeability) over an extensive portion of the bed, as would be required by the concept, seems doubtful.

TABLE 6.1
SUMMARY OF FLOWS

Period	Days	Litres/Day				100 Seepage (Seepage + Runoff)
		Rain	Seepage	Runoff	Evaporation	
6/4/82-11/4/82	6	324.3	125.0	23.3	202.3	84.3
12/4/82-24/4/82	15	171.4	16.7	0.0	162.4	-
27/4/82-28/5/82	32	164.8	48.1	58.9	77.6	45.0
29/5/82-20/6/82	23	170.3	17.3	28.0	145.9	38.2
21/6/82-18/7/82	28	169.8	21.8	21.5	158.6	50.3
19/7/82-15/8/82	28	165.5	26.2	18.6	136.9	58.5
16/8/82-12/9/82	28	165.5	28.4	12.7	134.8	69.1
13/9/82-10/10/82	28	164.0	40.0	18.1	107.7	68.8
11/10/82-7/11/82	28	164.0	45.6	24.6	87.4	65.0
8/11/82-5/12/82	28	160.3	45.5	19.1	112.0	70.4
6/12/82-10/1/83	36	157.8	24.5	11.8	154.9	67.5
11/1/83-30/1/83	20	151.9	16.9	11.1	158.9	60.4
31/1/83-27/2/83	28	160.3	8.5	10.3	190.3	45.2
28/2/83-27/3/83	28	157.1	11.2	10.0	192.4	52.8
Average	356	162.9	29.5	19.9	139.4	59.7
28/3/83-24/4/83	22	152.5	9.0	9.8	187.9	47.9
25/4/83-22/5/83	28	176.3	32.6	21.6	153.8	60.2
23/5/83-19/6/83	28	170.5	21.6	20.4	192.9	51.4
20/6/83-11/7/83	22	172.0	14.3	14.2	212.2	50.2
Average	100	149.8	20.3	17.0	185.2	54.4
12/7/83-15/7/83	4	2,536.3	787.5	465.0	178.6	62.9
22/10/83-31/10/83	11	172.7	36.2	16.2	124.7	69.1
1/11/83-30/11/83	30	155.0	32.0	16.0	162.3	66.7
1/12/83-31/12/83	31	171.2	39.1	20.2	140.7	66.0
1/1/84-31/1/84	31	172.5	40.3	20.6	148.0	66.2
1/2/84-29/2/84	27	171.6	42.2	21.6	142.8	66.1
1/3/84-31/3/84	31	173.2	42.8	28.5	160.2	60.1
1/4/84-30/4/84	30	162.8	28.0	19.4	186.0	59.1
1/5/84-31/5/84	27	168.9	37.9	24.1	154.8	61.1
Average	218	168.6	37.4	21.2	154.8	63.8
Overall Average	678	176.7	35.2	22.5	143.8	61.0

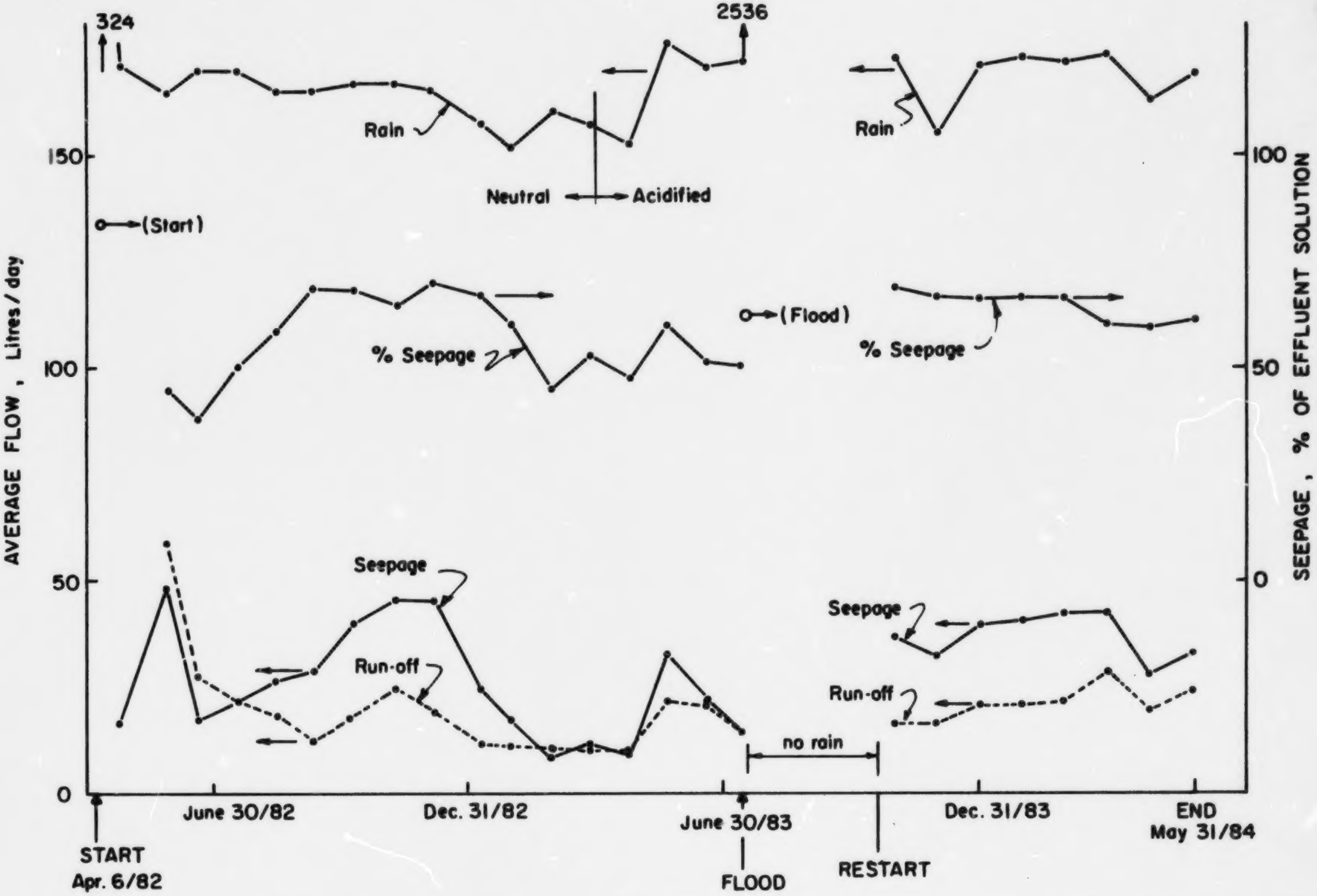


FIGURE 6-1 RAIN, SEEPAGE & RUN-OFF vs TIME

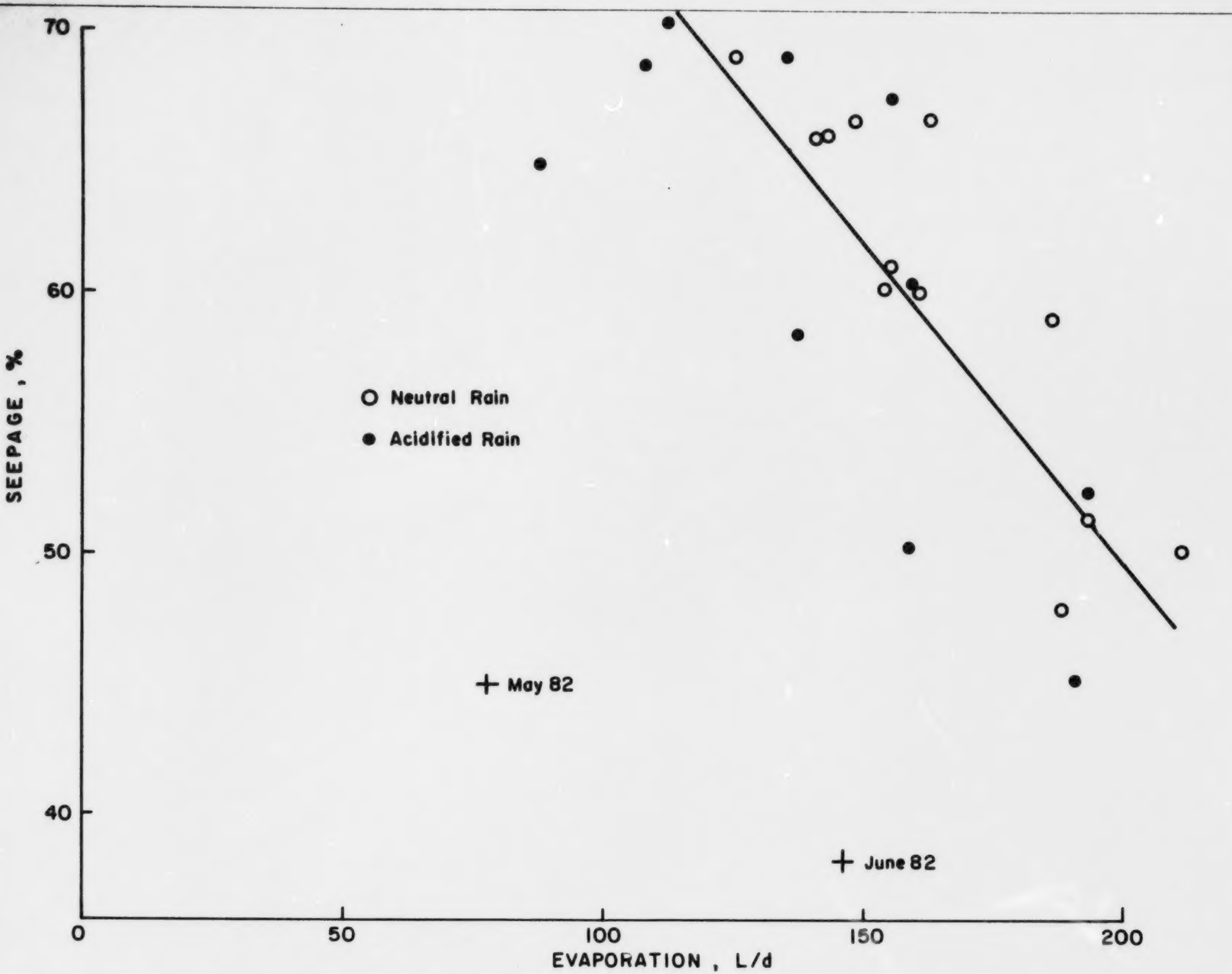


FIGURE 6-2 SEEPAGE vs EVAPORATION

6.2 Analysis of Solutions

Analysis of the effluent solutions for pH, U, As, Ni, and Ra-226 is presented in Tables 6.2 and 6.3. The pH was obtained by averaging daily measurement (Appendix F); detailed results for the metals over the periods 6/4/82-31/5/84 are shown in Appendix H.

Except for radium assays, the solutions were filtered before analysis.

6.2.1 pH of the Solutions

The change in average pH with time is illustrated in Figure 6.3. The pH of the seepage solution declined marginally over the 12-month period of neutral rain from about 11 to 7. The change to acidified rain for a further 3 1/2 months appears to have made little difference. On restart with acidified rain in October 1983, the average pH remained close to 7 for the whole 7-month period.

The pH of the runoff solution showed no trend during the project, with an average value of about 7.5. The runoff average pH was consistently lower than that of the seepage for the first eleven months; thereafter it was almost always higher by about 0.4 units.

The pH of both solutions rose during the flood (acidified) period.

The decline in pH of the seepage during the period of neutral rain may be caused by the gradual conversion of calcium hydroxide in the bed to calcium carbonate by reaction with atmospheric carbon dioxide and subsequently to calcium sulphate under acid rain conditions. The lime in the upper layers of the bed seen by runoff solution, having readier access to the carbon dioxide, would presumably be converted much more quickly.

This hypothesis however does not account for the minor but consistent difference in pH during the second half of the program.

TABLE 6.2
ANALYSIS OF SEEPAGE SOLUTION

Period	Flow (L)	pH	U (mg/L)	As (mg/L)	Ni (mg/L)	Ra (pCi/L)
6/4/82-11/4/82	750	11.4	1.11	7.9	0.15	12.0
12/4/82-26/4/82	250	8.9	1.32	13.1	0.12	14.3
27/4/82-28/5/82	1,538	11.3	0.62	4.83	0.12	15.6
29/5/82-20/6/82	397	10.4	1.74	15.2	0.12	9.9
21/6/82-18/7/82	610	9.2	0.64	3.80	0.11	23.3
19/7/82-15/8/82	733	8.4	0.49	5.25	0.14	28.1
16/8/82-12/9/82	796	8.2	0.88	2.82	0.14	22.9
13/9/82-10/10/82	1,119	8.7	0.45	2.97	0.07	26.9
11/10/82-7/11/82	1,277	7.6	0.60	4.04	0.10	26
8/11/82-5/12/82	1,275	8.3	0.80	5.1	0.05	33
6/12/82-10/1/83	882	7.5	0.85	4.7	0.05	30
11/1/83-30/1/83	338	7.9	0.61	2.07	0.01	24
31/1/83-27/2/83	239	7.4	1.71	13.4	0.04	27
28/2/83-27/3/83	313	6.9	1.15	4.4	0.02	42
Average/total	10,517	-	0.79	5.28	0.094	24.1
28/3/83-24/4/83	198	7.1	1.00	14.4	0.07	47.0
25/4/83-22/5/83	914	7.1	0.89	7.45	0.06	181.0
23/5/83-19/6/83	604	7.1	1.68	6.3	0.13	329.0
20/6/83-11/7/83	315	6.2	0.78	5.3	0.08	250.0
Average/total	2,031	6.88	1.12	7.47	0.085	222.7
12/7/83-18/7/83	3,222	7.7	4.2	45.88	0.397	220.9
22/10/83-31/10/83	398	7.0	1.8	12.0	0.22	N/A
1/11/83-30/11/83	960	7.2	1.4	9.5	0.33	38.7
1/12/83-31/12/83	1,213	6.8	1.0	8.5	0.14	41.6
1/1/84-31/1/84	1,250	6.7	1.1	9.5	0.12	65.7
1/2/84-29/2/84	1,140	6.8	1.2	11	0.10	125.5
1/3/84-31/3/84	1,327	7.0	1.0	11	0.10	19.0
1/4/84-30/4/84	839	7.3	1.1	12	0.10	69.3
1/5/84-31/5/84	1,024	6.8	1.1	12	0.10	76.5
Average/total	8,151	6.95	1.15	10.50	0.14	61.2

TABLE 6.3
ANALYSIS OF SEEPAGE SOLUTION

Period	Flow (L)	pH	U (mg/L)	As (mg/L)	Ni (mg/L)	Ra (pCi/L)
6/4/82-11/4/82	140	7.1	1.6	14.4	0.21	6
12/4/82-26/4/82	0	7.5	1.35	-	-	7
27/4/82-28/5/82	1,886	7.5	1.30	26.3	0.20	4.3
29/5/82-20/6/82	643	7.5	1.75	31.6	0.13	6.7
21/6/82-18/7/82	602	7.4	1.55	27.5	0.10	5.8
19/7/82-15/8/82	521	7.7	0.86	24.1	0.10	8.7
16/8/82-12/9/82	356	7.7	1.09	23.4	0.13	7.2
13/9/82-10/10/82	507	7.7	1.20	21.9	0.19	8.0
11/10/82-7/11/82	688	6.8	0.75	20.9	0.30	12
8/11/82-5/12/82	534	7.4	0.90	19.7	0.20	11
6/12/82-10/1/83	424	7.3	0.95	18.9	0.10	5
11/1/83-30/1/83	221	7.6	2.34	24.3	0.10	6
31/1/83-27/2/83	289	7.1	1.50	9.6	0.40	16
28/2/83-27/3/83	281	7.5	1.19	18.2	0.20	12
Average/total	7,092	-	1.25	23.5	0.18	7.5
28/3/83-24/4/83	215	7.5	1.51	15.9	0.03	17
25/4/83-22/5/83	605	7.7	1.43	15.9	<0.01	23
23/5/83-19/6/83	571	7.4	1.50	17.2	0.03	18
20/6/83-11/7/83	313	6.6	1.16	15.5	0.03	12
Average/total	1,704	7.3	1.41	15.7	0.023	18.5
12/7/83-18/7/83	1,928	7.3	0.257	5.8	0.077	9.4
22/10/83-31/10/83	178	7.6	1.2	7.3	0.11	N/A
1/11/83-30/11/83	480	7.6	0.82	7.1	0.64	25.3
1/12/83-31/12/83	625	7.1	0.80	9.4	0.02	110.0
1/1/84-31/1/84	638	7.2	0.85	12	0.03	23.9
1/2/84-29/2/84	584	7.3	0.87	12	0.01	67.2
1/3/84-31/3/84	882	7.6	0.80	13	0.03	18.7
1/4/84-30/4/84	581	7.6	0.67	12	0.04	17.0
1/5/84-31/5/84	651	7.2	0.48	11	0.06	26.3
Average/total	4,619	7.4	0.77	11.0	0.10	40.3

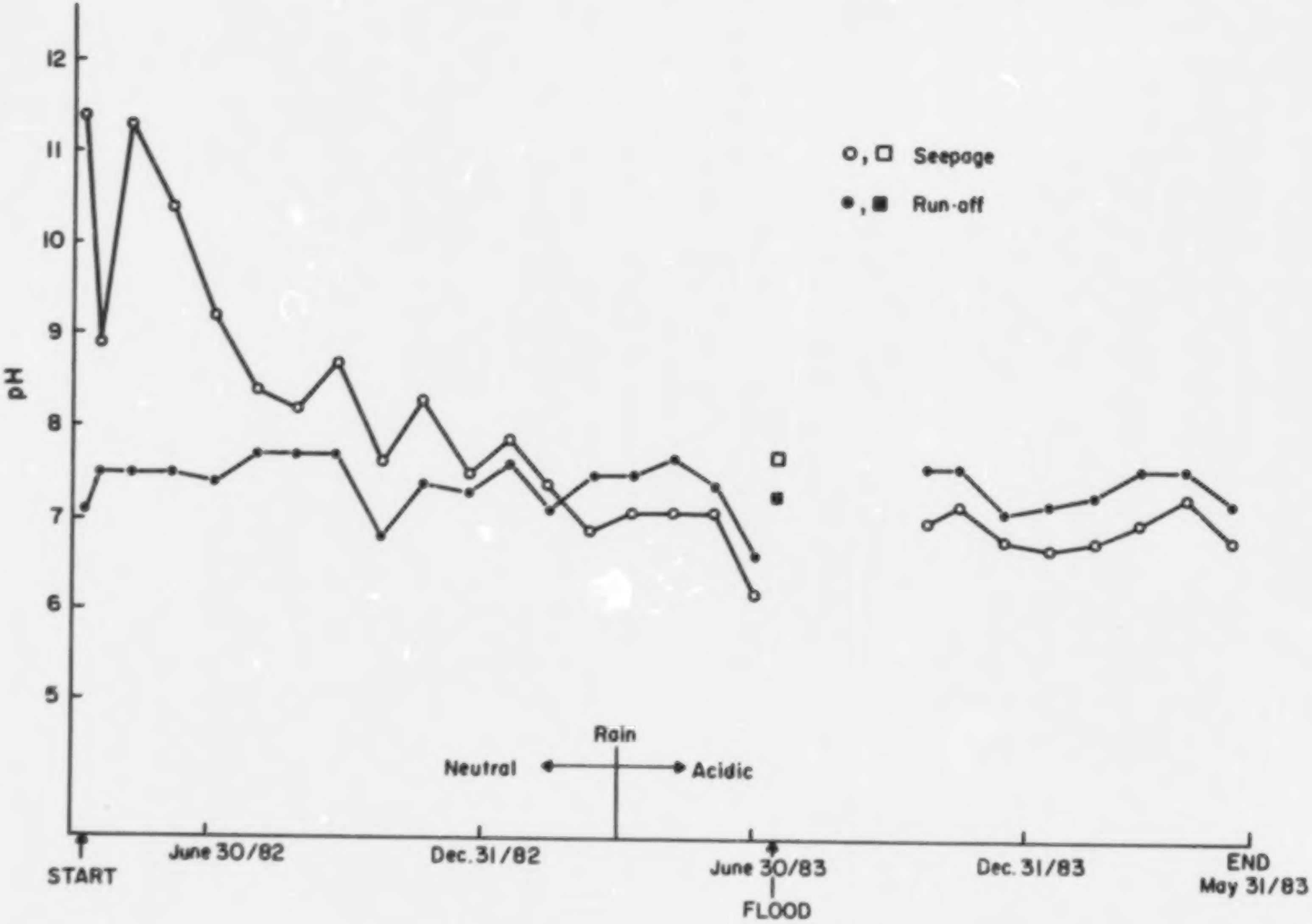


FIGURE 6-3 pH OF EFFLUENT SOLUTIONS vs TIME

6.2.2 Radium in Solution

Radium concentrations in the solutions are illustrated in Figures 6.4 and 6.5. Concentrations rose irregularly during the first 15 months, ranging from 9.9 - 42 pCi/L for the seepage and 4.3 - 16 pCi/L for runoff solution. Concentrations were trendless over the final 7 1/2 months, averaging 61 and 40 pCi/L for seepage and runoff, respectively.

6.2.3 Uranium in Solution

The uranium concentration in the effluent solutions is illustrated in Figure 6.6.

The concentration in the seepage averaged lower than that in the runoff during the first 15 months of monitoring, but was consistently higher during the final 7 1/2 month period.

Seepage concentration was at a maximum during the flood, whereas the runoff was at a minimum during this period. The concentration in the runoff showed a declining trend during the final four months of operation.

6.2.4 Arsenic in Solution

Arsenic concentration in runoff solution decreased during the first 15 months (Figure 6.7) from initial values of about 30 mg/L to about 10 mg/L, and averaged 11 mg/L over the final 7 1/2 months.

Seepage arsenic levels were quite variable, but the average for the final 7 1/2 months was about the same as in the runoff during this period. This level (10.5 mg/L) was about double that of the first 15 months.

Seepage concentration reached a maximum (45.9 mg/L) during the flood; runoff concentration during the flood was at a minimum (5.8 mg/L).

6.2.5 Nickel in Solution

Nickel concentrations are illustrated in Figure 6.8

Seepage concentrations declined irregularly during the first 12 months, but appeared to increase with acidification of the rain. Thereafter the concentrations were steady at about 0.1 mg/L.

Nickel in the runoff was generally higher than in the seepage for the first 12 months, but was less than seepage during the acidification periods, except for a brief period after the commencement of Phase IV - Part 2.

6.2.6 Comment

The concentrations of uranium, arsenic and nickel moved in sympathy to a marked degree. To illustrate this, normalized average solution analyses for uranium and nickel are plotted against the corresponding value for arsenic in Figure 6.9. Normalized concentrations are provided in Table 6.4.

TABLE 6.4
NORMALIZED SOLUTION CONCENTRATIONS

Period	Uranium		Arsenic		Nickel	
	Seepage	Runoff	Seepage	Runoff	Seepage	Runoff
6/4/82-27/3/83	0.563	1.250	0.413	1.412	0.623	1.446
28/3/83-11/7/83	0.800	1.416	0.585	0.942	0.561	0.182
12/7/83-18/7/83	3.002	0.257	3.594	0.349	2.625	0.611
21/10/83-31/5/84	0.823	0.773	0.822	0.661	0.939	0.779
Average	1.000	1.000	1.000	1.000	1.000	1.000

The increase in seepage concentrations may be explained as an increase in solubility as the pH of the seepage decreased over the project.

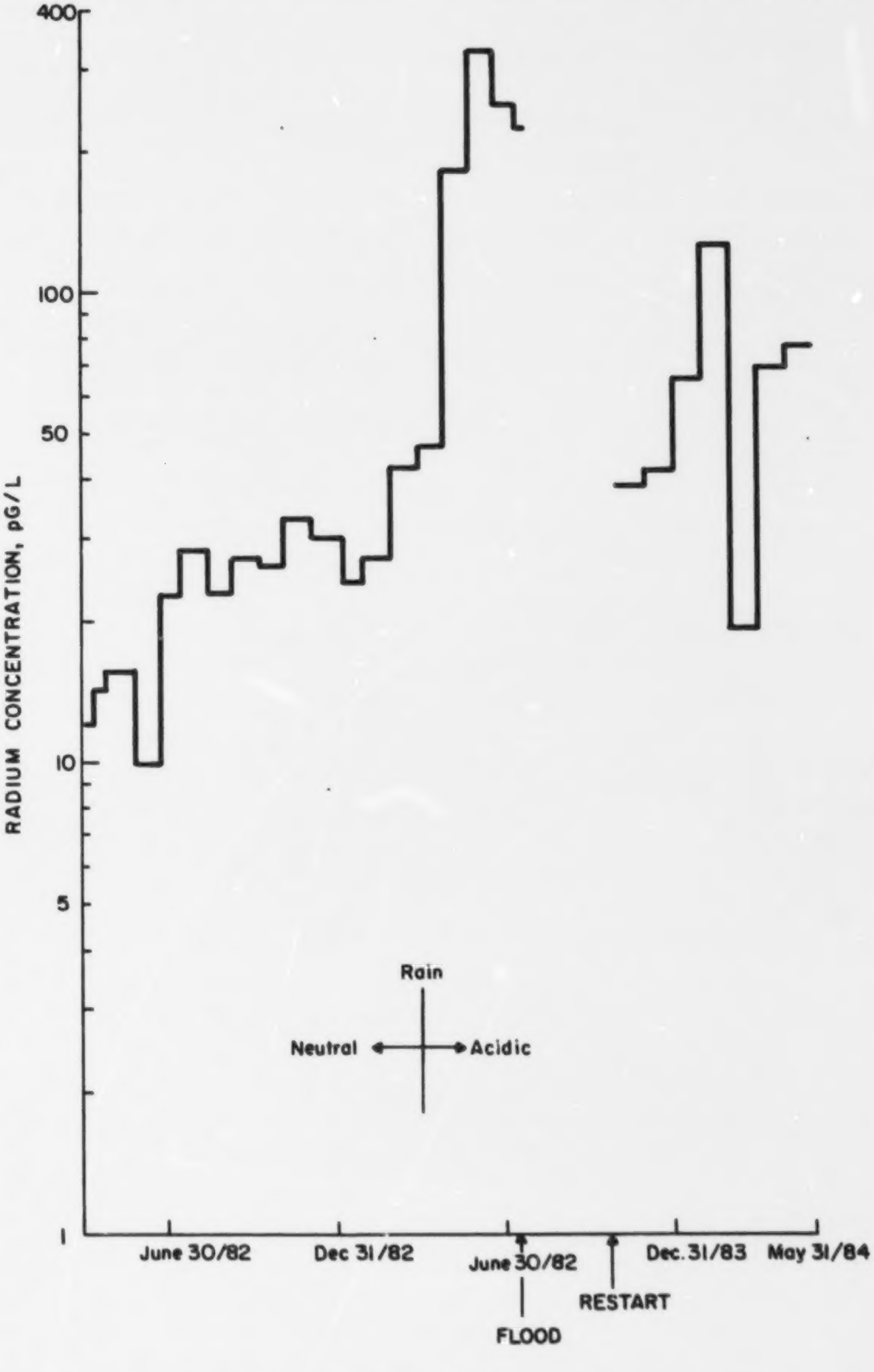


FIGURE 6·4 SEEPAGE RADIUM CONCENTRATION vs TIME

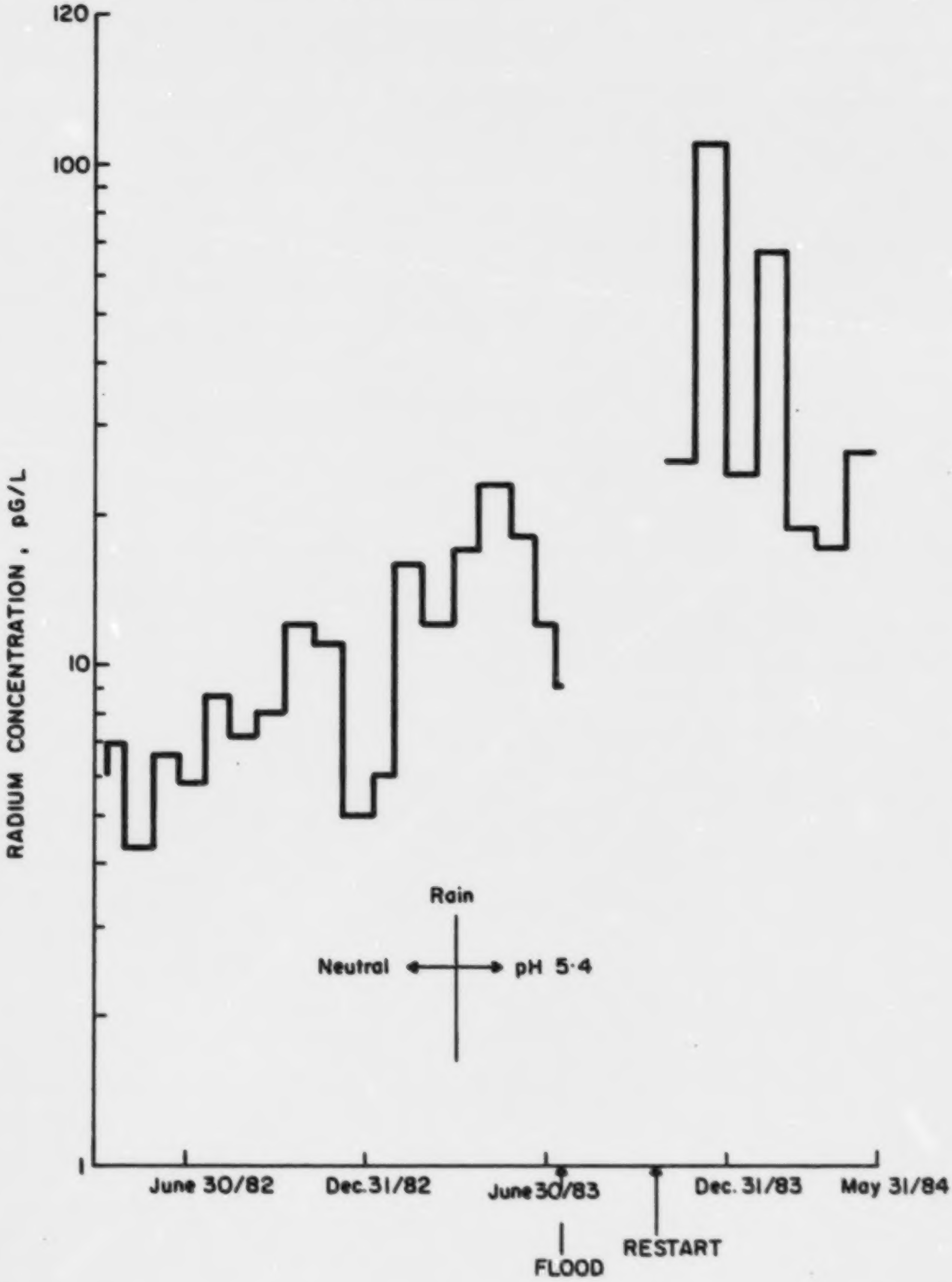


FIGURE 6·5 RUN-OFF SOLUTION RADIUM CONCENTRATION vs TIME

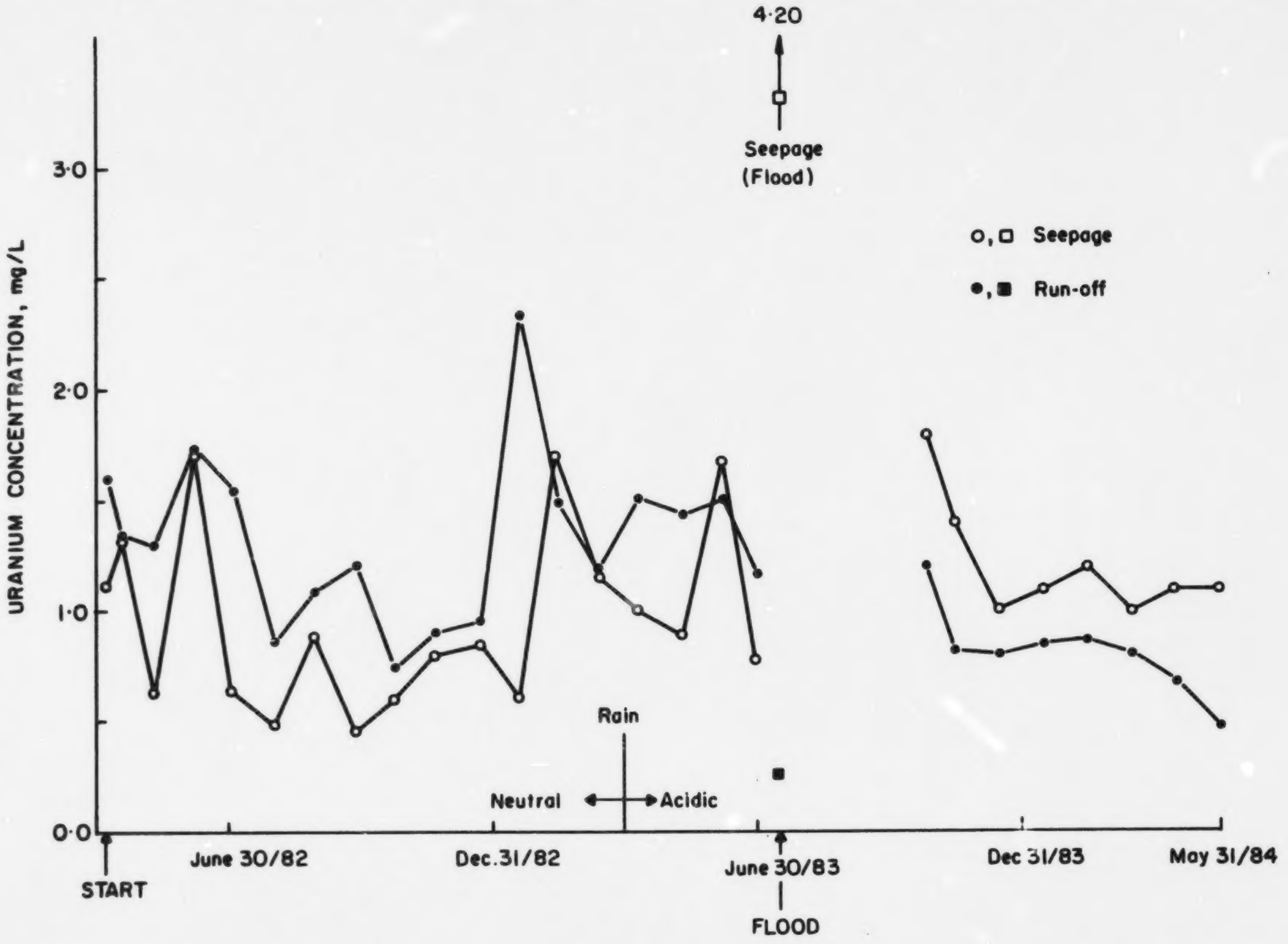


FIGURE 6·6 URANIUM IN EFFLUENT SOLUTIONS vs TIME

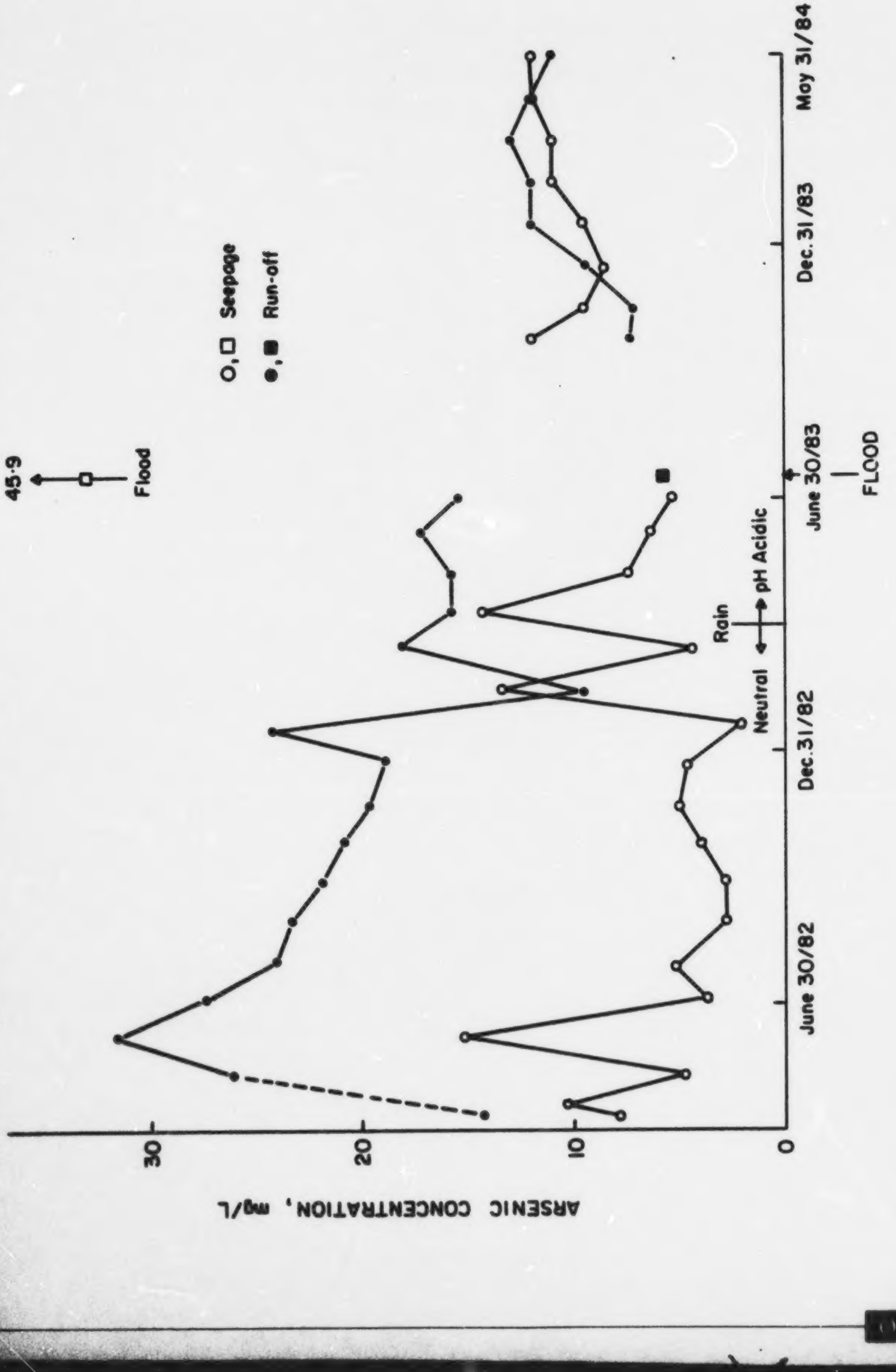


FIGURE 6·7 ARSENIC IN EFFLUENT SOLUTIONS vs TIME

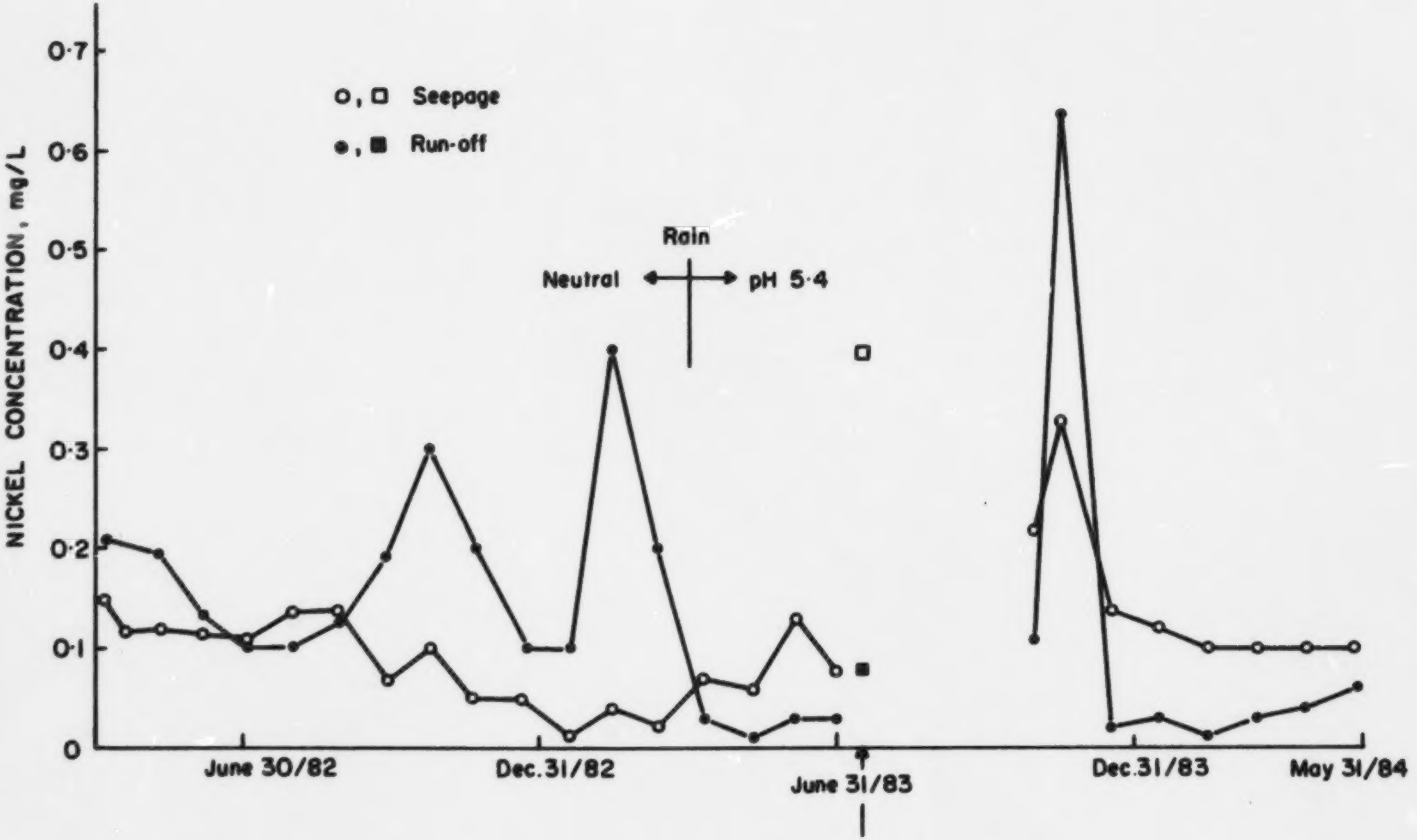


FIGURE 6·8 NICKEL CONCENTRATION IN EFFLUENT SOLUTIONS vs TIME

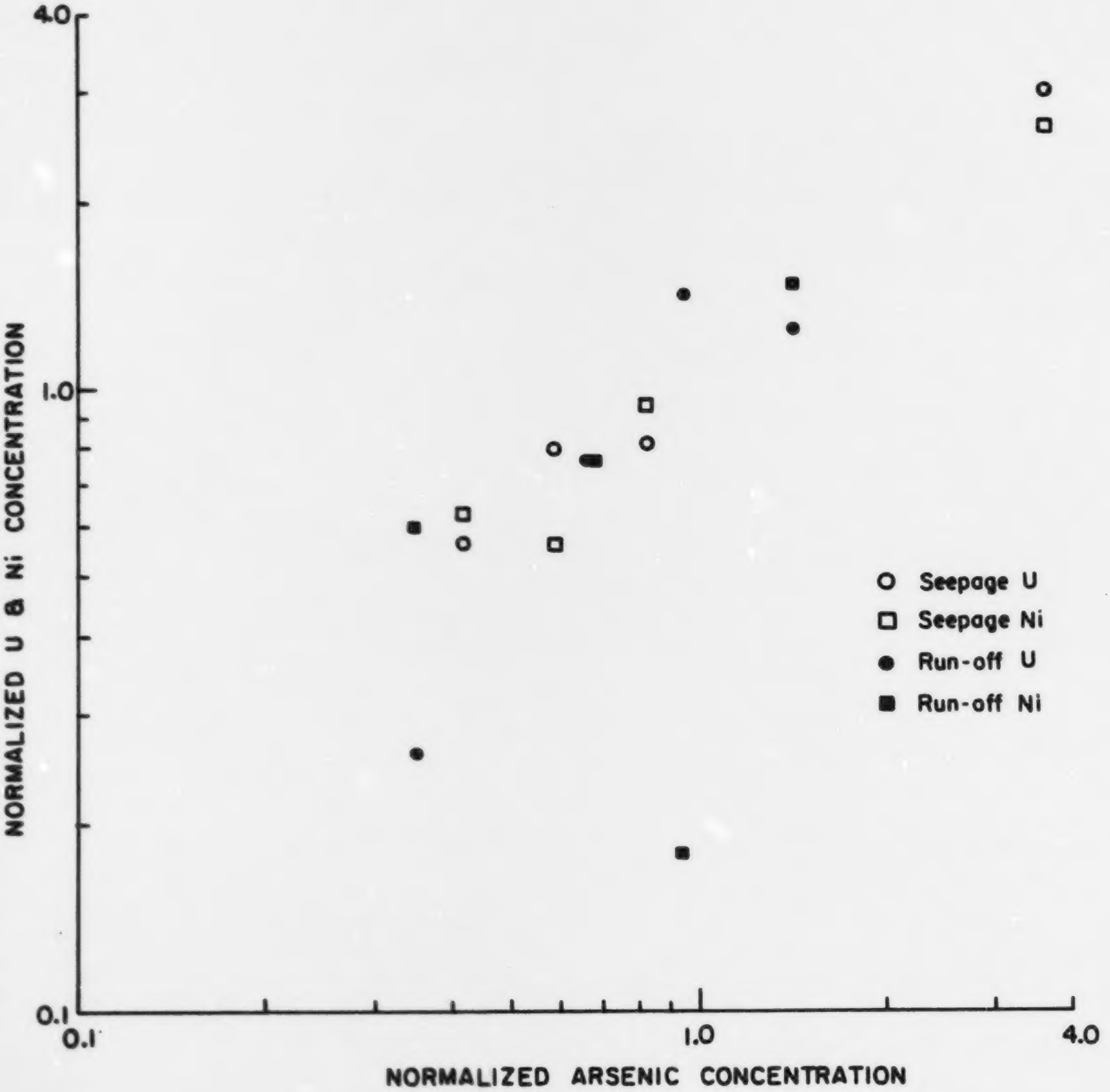


FIGURE 6·9 NORMALIZED U & Ni CONCENTRATION vs NORMALIZED ARSENIC CONCENTRATION.

The concentrations in runoff solution, however, generally decreased over the project in the face of no general change in pH. It was observed that as the surface of pile gradually became encrusted, the runoff appeared to flow over the surface and off the bed more rapidly, affording a decreased opportunity for metal dissolution to occur. The effect would be expected to be heightened during the flood period (12/7/83-18/7/83), explaining some of the particularly low values then found.

The high values found in the flood seepage are not explained.

6.2.7 Na, K, Mg, Ca, Ba, Fe and SO_4" in Solution

The concentrations of these ions in solutions are presented in Table 6.5

TABLE 6.5

CONCENTRATIONS OF Na, K, Mg, Ca, Ba, Fe_2SO_4 IN SEEPAGE AND RUNOFF

Element	26/7/82-22/8/82		25/10/82-21/11/82		28/2/83-27/3/83		18/7/83	
(mg/L)	Seepage	Runoff	Seepage	Runoff	Seepage	Runoff	Seepage	Runoff
Fe	0.09	0.08	0.08	0.11	0.03	0.03	0.05	0.1
Ca	427	282	508	260	525	188	621	196
Mg	1.67	14.4	1.65	12.08	2	9	4.87	22.4
K	34.0	17.1	25.4	6.0	16	4	16	4.4
Na	353	34.7	260	34.7	88	24	151	38.3
Ba	0.05	0.08	0.08	0.08	-	-	-	-
SO_4	1520	630	1500	580	-	-	1900	530

The contents of Ca, K, Na in the seepage would appear sufficient to suggest the dissolution and migration of these metals. The Mg content of the seepage is below the typical value for pilot plant tap water (8 mg/L), suggesting it is being precipitated from the applied rain water.

Table 6.5 illustrates that the seepage solutions have higher concentrations of Na, K, Ca, and SO_4 compared with the runoff.

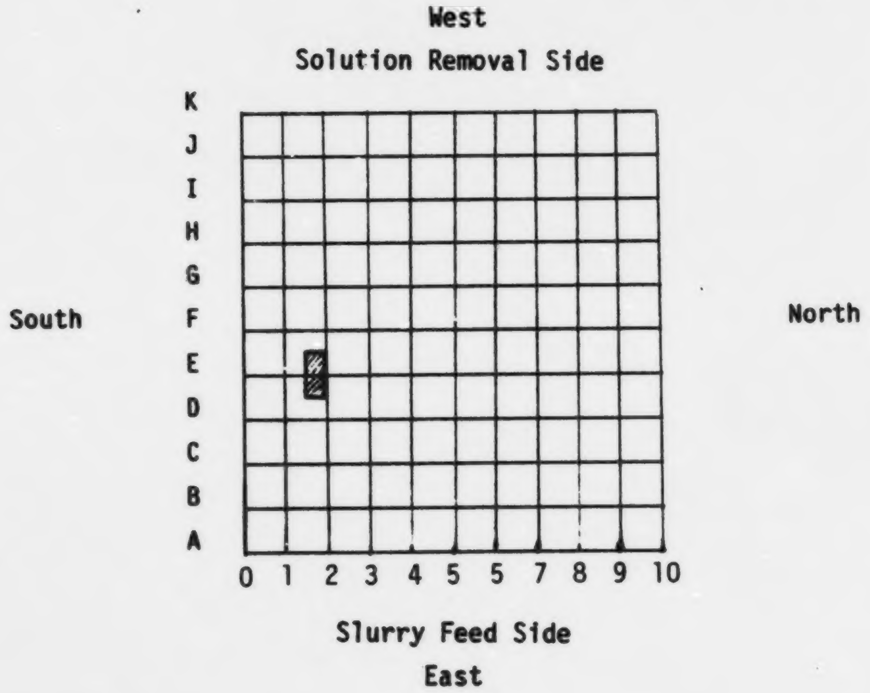
Both Fe and Ba have similar concentrations in both the seepage and runoff. The Fe values are probably too low to support sulphide oxidizing organisms. This is significant because the sulphides occuring in this deposit are low in Fe and high in Ni and As. The potential for the generation of sulphuric acid in the pore solutions may thus be low.

7. CHARACTERISTICS OF THE TAILINGS BED

7.1 Physical Characteristics

7.1.1 General

An imaginary horizontal rectangular 10 by 10 grid was imposed on the tailings surface in order to identify the points at which samples were extracted. Equilateral lines parallel to the slurry feed and solution removal side were labelled A to J. Lines parallel to the other side of the facility were numbered 0 - 10.


West
Solution Removal Side
South
North
K
J
I
H
G
F
E
D
C
B
A
0
1
2
3
4
5
5
7
8
9
10
Slurry Feed Side
East

Freeze-thaw section is located in the shaded area.

Sample cores were extracted at the following positions:

Date	Positions
March 31, 1982	B1, B9, F1, F9
May 31, 1982	B3, B7, H1, H9
July 26, 1982	C1, C9, G1, G9
January 5, 1983	C2.25, C7.25, G2.25, G7.25
April 5, 1983	BC2.5, BC7.5, GH 2.5, GH 7.5
July 26, 1983	C2, C7, G2, G7, freeze-thaw
January 16, 1984	B1.5, B5, B8.5, E5, H1.5, H8.5, J5
March 31, 1984	Freeze-thaw section (stored)

The various physical characteristics of the tailings bed which can affect the removal of the different elements from the bed include:

- permeability,
- porosity,
- particle size distribution,
- temperature variation in the bed.

Physical testing of the core extracted from the freeze-thaw bed was reported by Golder Associates to be impossible. This was because the alternate freezing and thawing had destroyed the inherent structure of the bed. The physical integrity of the samples was thus destroyed, rendering the permeability testing meaningless.

7.1.2 Permeability

The rate at which a fluid can be transmitted through a bed is determined by its permeability. With porosity, permeability also determines the length of time pore fluids will be in contact with the solids (i.e. potential reaction time). Standard engineering practice defines the drainage characteristic of soil as follows:

ORI

- good if k (coefficient of permeability) lies between 10^2 and 10^{-4} cm/s,
- poor if k lies between 10^{-4} and 10^{-6} cm/s,
- practically impervious if $k < 10^{-6}$ cm/s.

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TABLE 7.1

SUMMARY OF CORE PERMEABILITY MEASUREMENTS

Southeast Location

Core Segment cm from Top	B3 May 31/82	C1 July 26/82	C2.25 Jan. 5/83	BC2.5 April 5/83	C2 July 26/83	B1.5 Jan. 16/84	Average
0 - 10	8.3×10^{-6}	-	-	6.3×10^{-6}	2.7×10^{-6}	1.1×10^{-5}	6.28×10^{-6}
10 - 20	3.4×10^{-6}	9.6×10^{-6}	7×10^{-6} 1.3×10^{-6}	3.5×10^{-6}	4.8×10^{-6}	3.4×10^{-6} 8.2×10^{-6}	4.39×10^{-6}
20 - 30	6.3×10^{-6} 1.2×10^{-6}	1.1×10^{-5} 6.7×10^{-6}	6.2×10^{-6} 6.0×10^{-6}	3.9×10^{-6}	3.7×10^{-6}	4.9×10^{-6} 6.7×10^{-6} 8.4×10^{-6}	4.25×10^{-6}
30 - 40	2.3×10^{-5}	6.6×10^{-6} 5.6×10^{-6}	-	4.2×10^{-6} 2.6×10^{-6}	5.6×10^{-6}	-	6.11×10^{-6}
40 - 50	-	3.0×10^{-6}	4.5×10^{-6} 6.5×10^{-6}	5.0×10^{-6}	4.1×10^{-6}	-	4.48×10^{6}
+50		-	-	-	3.9×10^{-6}	-	3.9×10^{-6}
Average	3.45×10^{-6}	4.46×10^{-6}	4.63×10^{-6}	4.09×10^{-6}	4.03×10^{-6}	6.63×10^{-6}	

Northeast Location

Core Segment cm from Top	B7 May 31/82	C9 July 26/82	C7.25 Jan. 5/83	BC7.5 April 5/83	C7 July 26/83	B8.5 Jan. 16/84	Average
0 - 10	3.1×10^{-5}	9.1×10^{-6}	-	6.7×10^{-6}	6.5×10^{-6}	2.6×10^{-6}	7.94×10^{-6}
10 - 20	4.6×10^{-6} 1.0×10^{-6} 3.9×10^{-7}	2.5×10^{-6} 5.2×10^{-6}	2.7×10^{-6} 3.7×10^{-6}	4.3×10^{-7} 5.5×10^{-6} 3.6×10^{-6}	5.3×10^{-6}	6.3×10^{-6} 3.2×10^{-6}	3.66×10^{-6}
20 - 30	8.0×10^{-6}	8.0×10^{-6}	4.3×10^{-6}	-	9.3×10^{-6}	5.1×10^{-5} 4.7×10^{-6}	9.22×10^{-6}
30 - 40	-	7.1×10^{-6} 1.4×10^{-6}	1.0×10^{-6} 1.0×10^{-5}	3.3×10^{-6}	7.9×10^{-6} 4.6×10^{-6}	6.2×10^{-6}	4.06×10^{-6}
40 - 50	-	-	-	3.5×10^{-6}	3.5×10^{-6}	-	3.5×10^{-6}
Average	3.38×10^{-6}	4.59×10^{-6}	3.37×10^{-6}	2.95×10^{-6}	5.87×10^{-6}	6.54×10^{-6}	

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Table 7.1 (continued)

Southwest Location

Core Segment cm from Top	H1 May 31/82	G1 July 26/82	G2.25 Jan. 5/83	GH2.5 April 5/83	G2 July 26/83	.H1.5 Jan. 16/84	Average
0 - 6	1.4×10^{-5}	7.0×10^{-7}	-	-	-	-	3.13×10^{-6}
6 - 11	3.2×10^{-6}	9.0×10^{-7}	2.7×10^{-6}	2.9×10^{-6}	7.2×10^{-6}	5.5×10^{-6}	3.11×10^{-6}
11 - 16	-	4.6×10^{-6}	9.0×10^{-7}	3.8×10^{-8} 4.3×10^{-6}	9.4×10^{-6}	7.2×10^{-6}	2.00×10^{-6}
16 - 21	5.9×10^{-6}	1.3×10^{-6}	2.5×10^{-6} 8.5×10^{-6}	-	1.3×10^{-5}	7.1×10^{-6}	4.97×10^{-6}
21 - 26	-	2.0×10^{-6}	1.0×10^{-5}	-	2.2×10^{-5}	4.7×10^{-6}	6.74×10^{-6}
26 - 31	-	2.7×10^{-6}	6.3×10^{-6}	3.0×10^{-6} 7.2×10^{-6}	3×10^{-5}	1.1×10^{-5}	7.03×10^{-6}
+31	-	-	-	2.9×10^{-6}	2.3×10^{-5}	3.0×10^{-6}	5.85×10^{-6}
Average	6.42×10^{-6}	1.65×10^{-6}	3.85×10^{-6}	1.76×10^{-6}	15.4×10^{-6}	5.93×10^{-6}	

Northwest Location

Core Segment cm from Top	H9 May 31/82	G9 July 26/82	G7.25 Jan. 5/83	GH7.5 April 5/83	G7 July 26/83	H8.5 Jan. 16/84	Average
0 - 6	2.0×10^{-6}	5.7×10^{-7}	-	-	-	-	1.07×10^{-6}
6 - 11	1.9×10^{-6}	3.5×10^{-6}	4.0×10^{-6}	5.8×10^{-6}	4.0×10^{-6}	1.8×10^{-5} 5.4×10^{-6}	4.81×10^{-6}
11 - 16	4.7×10^{-6} 6.2×10^{-6}	8.7×10^{-6}	3.8×10^{-6} 2.6×10^{-6}	-	2.6×10^{-6}	2.0×10^{-6}	4.0×10^{-6}
16 - 21	-	1.2×10^{-6}	-	1.9×10^{-6}	6.0×10^{-6}	3.0×10^{-6}	2.53×10^{-6}
21 - 26	8.1×10^{-6}	4.7×10^{-6}	-	6×10^{-6}	1.4×10^{-6}	5.8×10^{-6}	4.51×10^{-6}
26 - 31	-	8.8×10^{-6}	3.6×10^{-7}	1.1×10^{7} 8.2×10^{-7}	4.0×10^{-6}	-	1.03×10^{-6}
+31	-	-	7.4×10^{-6} 1.0×10^{-5}	7×10^{-6}	7.9×10^{-6}	6.3×10^{-6}	7.63×10^{-6}
Average	3.90×10^{-6}	3.08×10^{-6}	3.19×10^{-6}	1.86×10^{-6}	3.75×10^{-6}	5.46×10^{-6}	

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The permeability tests were performed by Golder Associates. The results are shown in Appendix I and a summary of the results shown in Table 7.1. Because of the large variation in permeability (extremes were 8.3×10^{-8} and 3.1×10^{-5}), the geometric mean is employed for core averages.

The core averages (Table 7.2) do not demonstrate a systematic variation in permeability over the sampling period, nor any consistent difference between location.

TABLE 7.2

AVERAGE CORE PERMEABILITY ($\times 10^{-6}$) OVER SAMPLING PERIOD

Location	May 31/82	July 26/82	Jan. 5/83	April 5/83	July 26/82	Jan. 16/84	Average
S-E	3.45	4.46	4.63	4.09	4.03	6.63	4.5
N-E	3.38	4.59	3.37	2.95	5.87	6.54	4.3
S-W	6.42	1.65	3.85	1.76	15.4	5.93	4.3
N-W	3.90	3.08	3.19	1.86	3.75	5.46	3.4
Average	4.1	3.2	3.7	2.5	6.1	6.1	

The average permeability at different depths is shown in Table 7.3. No trend with depth is evident.

TABLE 7.3
AVERAGE CORE PERMEABILITY (x 10^{-6}) AT DIFFERENT DEPTHS

SE, NE		SE, NW	
Depth (cm)	Permeability	Depth (cm)	Permeability
0-10	7.06	0-6	1.83
10-20	4.01	6-11	3.87
20-30	6.26	11-16	2.83
30-40	4.98	16-21	3.55
40-50+	4.00	21-26	5.51
		26-31	2.69
		+31	6.68

The great range of measured permeabilities and the lack of a systematic relationship indicates the heterogeneous nature of the bed.

Areas of the bed containing above an average amount of fine material would be expected to have above normal moisture and less than normal permeability. However, no relationship between moisture (as received) and permeability can be seen (Figures 7.1 and 7.2). Golder Associates' report of July 5, 1983 (Appendix I) plotted permeability with moisture after the testing with little success.

7.1.3 Porosity

An examination of the physical characteristics obtained by Golder Associates during testing of the cores (see Appendix I) reveals a wide variation of the porosity throughout the tailings. No systematic relationship was established between porosity and the distribution of a particular element.

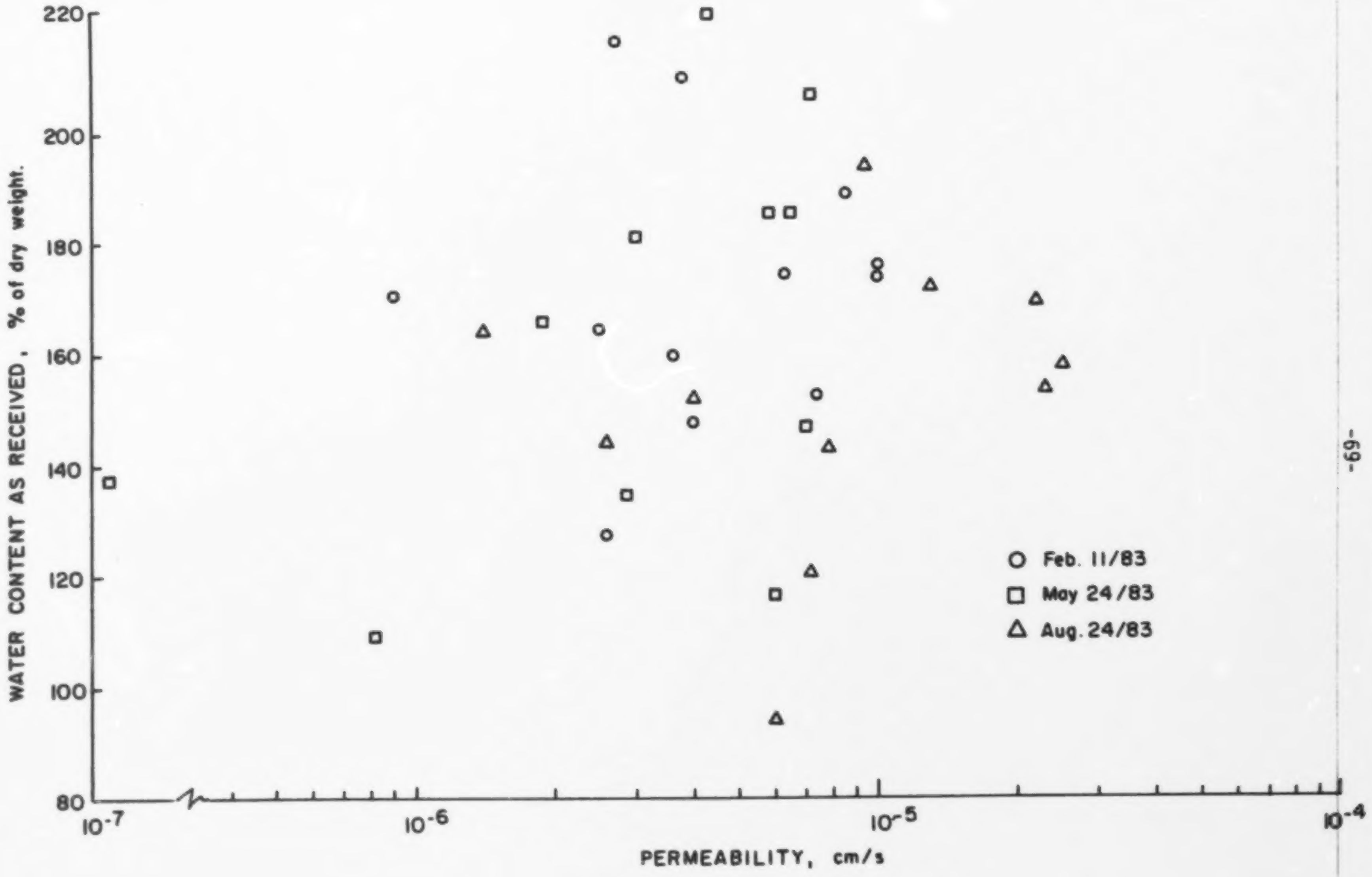

FIGURE 7·1 WATER CONTENT vs PERMEABILITY (G,H CORES)

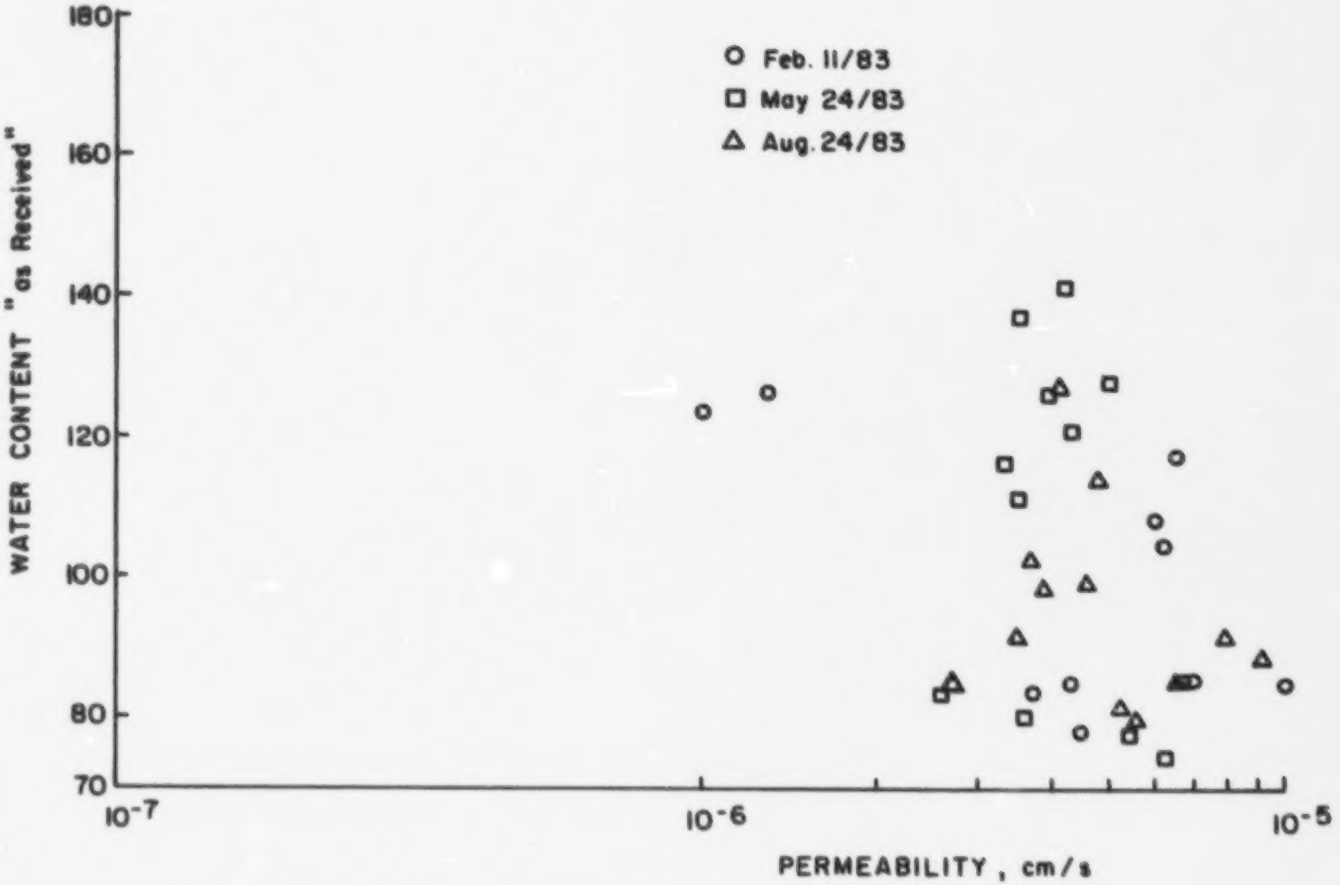

FIGURE 7·2 WATER CONTENT vs PERMEABILITY (B,C CORES)

The use of mercury porosimetry (see Appendix J) on dispersed aggregates of tailings bed material confirmed the heterogeneous nature of the tailings bed. The samples examined had porosities varying between 43 and 71%. The tests indicated the existence of a high proportion of partially blocked pores. The particle pore diameters varied between approximately 0.3 and 2.0 microns. It is suggested that because the porosity of the solids is high, the release of radon gas to the environment will be rapid if drying out of the bed takes place.

7.1.4 Particle Size Distribution within the Tailings Bed

The particle size distribution is important because it helps to determine the permeability and nature of the porosity within the tailings bed. It therefore influences the rate at which the water seeps through the bed or rises upwards by capillarity when the tailings bed surface is dried out.

Screen analysis of segments of core samples are provided in Appendix K, and the percent passing 12 microns is summarized in Table 7.4.

Size segregation of the feed during deposition, paralleling that which takes place in full scale tailings areas, is evident from the considerably higher fraction of minus 12 micron material in the core from the discharge side (F, G, H core) than found in the feed side (B, C) core.

The size distribution of the January 16, 1984 core was as follows:

Micron	B1.5, B5, B8.5	E5	H1.5, H8.5, J5
Size	Weight %	Weight %	Weight %
+74	72.6	56.1	25.3
-74 + 12	12.1	16.0	20.0
-12	15.3	27.9	54.7

No consistent trend of sizes with depth or time has been noted.

TABLE 7.4

CORE SEGMENTS, PERCENT PASSING 12 MICRONS

B-1		B-3		C2.25		BC2.5		C2		B-1.5	
April 1/82		May 31/82		Jan. 5/83		April 5/83		July 26/83		Jan. 6/84	
Depth (cm)	-12 µ	Depth (cm)	-12 µ	Depth (cm)	-12 µ	Depth (cm)	-12 µ	Depth (cm)	-12 µ	Depth (cm)	-12 µ
0-12	27.7	0-11	22.1	0-12.7	29.7	0-14	22.6	0-12	16.4	0-9.7	5.7
12-24	33.1	11-22	39.8	12.7-25.4	50.0	14-26.8	39.2	12-24	33.6	9.7-19.4	13.4
24-36	42.2	22-33	34.8	25.4-38.1	47.8	26.8-39.6	39.9	24-36	30.3	19.4-29.1	13.4
				38.1-55.9	35.4	39.6-52.4	40.1	36-48	31.9	29.1-38.8	14.6
										38.8-48.5	9.6
										48.5-58	11.6
0-36	34.3	0-33	32.2	0-55.9	40.7	0-52.4	35.4	0-48	28.0	0-58	11.4

B-9		B-7		C7.25		BC7.5		C7		B-8.5	
April 1/82		May 31/82		Jan. 5/83		April 5/83		July 26/83		Jan. 6/84	
Depth (cm)	-12 µ	Depth (cm)	-12 µ	Depth (cm)	-12 µ	Depth (cm)	-12 µ	Depth (cm)	-12 µ	Depth (cm)	-12 µ
0-12	29.2	0-8	41.7	0-12.7	51.1	0-13	40.1	0-12	34.1	0-9.7	15.8
12-24	44.8	8-16	34.3	12.7-25.4	48.6	13-25	43.3	12-24	37.5	9.9-19.4	30.4
24-36	34.1	16-24	33.1	25.4-38.1	30.6	25-37	28.2	24-36	34.5	19.4-29.1	19.1
				38.1-50.8	38.1	37-49	29.4	36-48	44.7	29.1-38.8	21.7
										38.8-48.5	16.0
										48.5-58	10.7
0-36	36.0	0-24	36.4	0-58.8	42.1	0-49	35.3	0-48	37.7	0-58	19.0

Table 7.4 (continued)

F-1		H-1		G2.25		GH2.5		G7		H 1.5	
April 1/82		May 31/82		Jan. 5/83		April 5/83		July 26/83		Jan. 16/84	
Depth (cm)	-12 μ	Depth (cm)	-12 μ	Depth (cm)	-12 μ	Depth (cm)	-12 μ	Depth (cm)	-12 μ	Depth (cm)	-12 μ
0- 5	39.6	0- 8	55.5	0-5.7	35.2	0- 4.5	35.0	0- 6	25.8	0- 6.8	54.8
5-10	66.3	8-16	44.8	5.7-11.4	59.5	4.5- 9.6	22.4	6-12	59.4	6.8-13.6	47.5
10-15	50.5	16-23	70.3	11.4-17.1	56.8	9.6-14.7	45.6	12-18	67.7	13.6-20.4	57.5
				17.1-22.9	64.7	14.7-19.8	52.0	18-24	67.2	20.4-27.2	67.7
				22.9-28.6	62.9	29.8-24.9	72.7	24-30	77.3	27.2-34	55.6
				28.6-34.3	49.9	24.9-30.0	71.3	30-36	68.5	34.0-40.8	30.0*
0-15	52.1	0-23	56.9	0-34.3	54.8	0-30.0	49.8	0-36	61.0	0-34.0	56.6

F-1		H-1		G7.25		GH7.5		G7		H 8.5	
April 1/82		May 31/82		Jan. 5/83		April 5/83		July 26/83		Jan. 6/84	
Depth (cm)	-12 μ	Depth (cm)	-12 μ	Depth (cm)	-12 μ	Depth (cm)	-12 μ	Depth (cm)	-12 μ	Depth (cm)	-12 μ
0- 5	57.7	0- 7	52.8	0- 5.7	55.0	0- 4.9	55.6	0- 6	44.5	0-10.2	35.3
10-15	47.7	7-14	62.9	5.7-11.4	54.0	4.9-10	66.8	6-12	52.7	10.2-20.4	40.0
10-15	46.3	14-23	57.9	11.4-17.1	52.2	10.0-15.1	65.3	12-18	18.2	20.4-30.6	57.5
				17.1-22.9	68.2	15.1-20.2	72.7	18-24	80.8	30.6-40.8	61.5
				22.9-28.6	59.9	20.2-25.3	84.9	24-30	71.5	40.8-51.0	52.9
				28.6-34.3	65.6	25.3-30.4	73.1	30-36	64.1	51.0-61.2	26.9*
0-15	50.6	0-23	57.9	0-34.3	59.2	0-30.4	69.7	0-36	55.3	0-51	49.4

B-5		E-5		J5	
Jan. 16/84		Jan.16/84		Jan. 16/84	
Depth (cm)	-12	Depth (cm)	-12	Depth (cm)	-12
0-10.2	13.1	0-8.3	16.8	0- 4.5	52.7
10.2-20.4	24.0	8.3-16.6	20.9	4.5- 9.0.	63.3
20.4-30.6	37.9	16.6-24.9	28.2	9.0-13.5	21.7*
30.6-40.8	34.2	24.9-33.2	30.6	13.5-18.0	2.7*
40.8-51.0	35.8	33.2-41.5	38.0	18.0-22.5	2.4*
51.0-61.2	42.0	41.5-50.0	33.1	22.5-27.0	3.3*
0-61.2	31.2	0-50.0	27.9	0- 9	58.0

* The bottom segment evidently included construction sand

As would be expected, moisture of the discharge side cores is consistently higher than the feed side, as befits their downslope position and finer size distribution. The following moisture data are from the January 16, 1984 core.

Core Segment (from top)	% Moisture		
	B1.5, B5, B8.5 (Feed Side)	E5 (Center)	H1.5, H8.5, J5 (Discharge Side)
1	31.2	40.9	52.3
2	36.4	46.5	54.2
3	37.8	51.2	58.7
4	40.8	48.4	54.6
5	34.5	53.5	57.1
6	37.4	48.7	-
Average	36.4	48.2	55.4

Although no relationship is apparent between the amount of fines and moisture content on individual core segments, feed side core averages suggest higher moisture is associated with a greater fines content (see Table 7.5). Since moisture is dependent on recent rainfall, evaporation, etc., the comparison is made between samples taken at the same time.

TABLE 7.5
FINES/MOISTURE CONTENTS OF FEED SIDE CORES

	- 12 Micron Fines - %		Moisture - %	
Core		Difference		Difference
B1	34.3	1.7	45.8	2.6
B9	36.0		48.4	
B3	32.2	4.2	43.3	3.5
B7	36.4		46.8	
C2.25	40.7	1.4	46.9	0.6
C7.25	42.1		47.5	
BC2.5	35.4	0.1	45.5	0.4
BC7.5	35.3		45.9	
C2	28.0	9.7	40.5	8.3
C7	37.7		48.8	
B1.5	11.4	7.6	32.4	9.4
B8.5	19.0		41.8	

7.2 Morphology of the Tailings Pit Surface

A series of photographs was taken in various directions across the lysimeter surface on July 15, 1982 and August, 1983. These are shown in Appendix Q.

Two characteristics appear in all of the photographs:

- large polygonal mudcracks occur randomly across the tailings pit surface;
- encrustation of efflorescent green and off-white salt deposits are widespread in the centre of the tailings pit.

The polygonal cracks are due to the shrinkage and swelling which takes place during the alternate wetting and drying of the surface layer. An analysis of the efflorescent deposits is provided in Table 7.6.

TABLE 7.6

SEMI-QUANTITATIVE ANALYSIS OF THE EFFLORESCENT CRUSTS

Element	Concentration Range Green Crystals (%)	Off-White Crystals (%)
Na	0.1	1.0
Mg	0.7	-
Al	0.03	-
Si	0.3	-
S	10-20	10-20
K	0.1	0.3
Ca	1.0	10-20
Ti	0.003	0.04
Fe	0.2	0.5
Co	0.2	0.5
Ni	10-20	0.6
Cu	0.01	0.02
Zn	0.004	0.02
As	0.5	2.0
Sr	0.005	0.005
Ba	0.07	0.2
Se	0.02	0.03
U	-	0.05
Mo	-	0.1
Zr	-	0.01

The analyses approximate hydrated nickel sulphate and calcium sulphate.

7.3 RADON FLUX EMANATIONS AT THE SURFACE OF THE TAILINGS BED

(Refer Appendix L)

Radon flux emanations on the surface of the bed were monitored on the freeze-thaw core as well as three other positions on the normal bed surface. The readings on the freeze-thaw bed were 5 pCi/m^2/s while this area was frozen on June 21, 1983, and 316 pCi/m^2/s on the same area after thawing out. Thus, freezing significantly reduces the radon emanations.

The radon flux measurements obtained on the surface of the tailings pile at various stages of the project are shown in Table 7.7.

The readings were taken at three locations on the tailings surface.

#1 near the heater
#2 in the middle
#3 on the far side from the heater

At location #3, farthest away from the heater, there is a trend to an increasing rate of radon emanations from the surface of the tailings. Two of the readings have been bracketted to indicate that the data appear to be anomalous. Also, the readings at locations #1 and #2 exhibit a significant reduction from before January 21, 1983. This could possibly be due to the fact that core had been withdrawn for testing close to these areas in the time period between December 9, 1982 and January 21, 1983.

TABLE 7.7
RADON FLUX MEASUREMENTS FROM TAILINGS PILE

($pCi/m^2/s$)

Date (1982 - 1983)	Location #1	Location #2	Location #3
June 18, 1982	271	167	30
June 24, 1982	254	235	28
July 20, 1982	165	216	66
September 7, 1982	145	120	(7)
September 29, 1982	246	(497)	228
October 29, 1982	341	356	118
December 9, 1982	270	253	123
January 21, 1983	79	96	212
March 3, 1983	91	83	245
May 13, 1983	89	79	280
July 6, 1983	95	58	234
July 29, 1983*	60	80	224
Nov. 24, 1983	90	178	59

NOTE: The numbers in brackets seem anamalous.

* The readings were taken shortly after a 10,000 litre flooding of the tailings pile.

7.4 Bacterial Assessment of the Tailings Bed (Refer Appendix M)

The tailings bed was monitored at each stage of the project to ascertain whether or not Thiobaccillus ferrooxidans was present. This micro-organism is commonly encountered in the tailings deposits at Elliot Lake, and catalyzes the reaction of the seepage solutions with the contained pyrite to produce dilute sulphuric acid solutions. These acidic solutions contribute to the remobilization and enrichment of the Ra-226 into seepage solutions.

All tests for these micro-organisms in the North Saskatchewan tailings pile proved negative. The results of the study by ORF's Environmental and Chemical Engineering Division showed that "Unless the tailings are neutralized to pH 4.0 or less, and an external source of iron and nutrients were available, *Thiobaccillus ferrooxidans* will not grow or be able to maintain viability on the CANMET tailings". Two cultures with different colony morphology, both Gram negative rods, were isolated from the tailings and runoff water.

7.5 Variation of the Elemental Content within the Bed

(Refer Appendix N)

7.5.1 General

The variation of the U, As, Ni and Ra-226 content in the tailings bed was measured by analyzing the depth segments of cores which were extracted at some 30 different positions in the tailings bed at selected intervals of time. The distribution of K, Mg, Ca, Cu, Ni, Zn, Pb, and So_4 were also determined in a few random samples. The positions of the cores and their dates of extraction are shown in Section 7.1.1.

The initial test work conducted by Knight and Piesold (see Appendix A) illustrated that the physical properties of the tailings pile varied both laterally and vertically after the deposition of the Canada Wide Mines Limited Pilot Plant Campaign tailings material. Testing of the tailings pile after the deposition of the CANMET Pilot Plant Campaign tailings also confirmed a lateral and vertical variation in the physical properties of the tailings bed. A similar variation in the distribution of various elements within the tailings bed can thus be anticipated.

7.5.2 Distribution of Arsenic and Nickel

Core segments were analyzed for arsenic and nickel, and the results are included in Appendix N. A summary of the core average assays is shown in Table 7.8. It covers the period from March 31, 1982 to January 16, 1984. The overall averages of 2.22% and 1.26% for As and Ni, respectively, closely approximate that of freshly processed tailings 2.1% As and 1.3% Ni.

No trend of the core averages with time is apparent but the discharge side core (F,G,H) consistently averaged higher in arsenic, and usually in nickel, than core taken from the feed side. This presumably results from the tendency of fines, including precipitates to flow to the downstream portion of the bed.

No trend of the core segment assays with depth were found.

A strong correlation exists between arsenic and nickel content. Nickel and arsenic assays of segments of core taken March 31 and May 31 (B1, B9, B3, B7) and, April 5 and July 26, 1983 (BC2.5, BC7.5, C2, C7) are plotted on Figure 7.3. Within reasonable limits the ratio of arsenic to nickel is constant, at about 5:3, presumably due to common host minerals (e.g. Niccolite NiAs, Gerdorffite NiAsS). Another source of arsenic is ferric arsenate, calcium arsenates and other process precipitates.

7.5.3 Distribution of Uranium

Uranium analysis of core segments is included in Appendix N. The surface layer usually (27 cases out of 31) contained a higher concentration of uranium than did the sample immediately below. Since the effect was present in the first suite of cores (March 31, 1982), it would appear to be an artifact of the pit operation rather than a migration phenomenon.

TABLE 7.8

AVERAGE NICKEL AND ARSENIC CONTENTS OF TAILING CORES

March 31/82		May 31/82		July 26/82		Jan. 5/83		April 5/83		July 26/83		Jan. 16/84		
Core	% As	Core	% As	Core	% As	Core	% As	Core	% As	Core	% As	Core	% As	Average
B1	2.07	B3	2.10	C1	1.83	C2	1.95	BC2.5	1.96	C2	1.39	B1.5	1.95	1.89
B9	1.99	B7	1.89	C9	2.18	C7	2.17	BC7.5	2.00	C7	1.81	B81.5	2.74	2.11
Avg.	2.03	Avg.	2.00	Avg.	2.01	Avg.	2.06	Avg.	1.98	Avg.	1.60	Avg.	2.34	2.00
F1	2.10	H1	2.13	G1	2.54	G2	2.52	GH2.5	2.79	G2	2.28	H1.5	2.81	2.45
F9	2.13	H9	2.19	G9	2.47	G7	2.52	GH7.5	2.60	G7	2.18	H8.5	2.75	2.40
Avg.	2.12	Avg.	2.16	Avg.	2.51	Avg.	2.52	Avg.	2.70	Avg.	2.24	Avg.	2.80	2.43
Avg.	2.08		2.08		2.26		2.29		2.34		1.92		2.57	2.22

March 31/83		May 31/82		July 26/82		Jan. 5/83		April 5/83		July 26/83		Jan. 16/84		
Core	% Ni	Core	% Ni	Core	% Ni	Core	% Ni	Core	% Ni	Core	% Ni	Core	% Ni	Average
B1	1.28	B3	1.35	C1	1.02	C2	1.14	BC2.5	1.19	C2	1.00	B1.5	0.97	1.14
B9	1.35	B7	1.16	C9	1.26	C7	1.30	BC7.5	1.20	C7	1.06	B8.5	1.37	1.24
Avg.	1.32	Avg.	1.26	Avg.	1.18	Avg.	1.22	Avg.	1.20	Avg.	1.03	Avg.	1.17	1.20
F1	1.21	H1	1.21	G1	1.40	G2	1.40	GH2.5	1.54	G2	1.24	H1.5	1.23	1.32
F9	1.05	H9	1.31	G9	1.56	G7	1.37	GH7.5	1.53	G7	1.21	H8.5	1.23	1.32
Avg.	1.13	Avg.	1.26	Avg.	1.48	Avg.	1.39	Avg.	1.54	Avg.	1.23	Avg.	1.23	1.32
Avg.	1.22		1.26		1.33		1.30		1.37		1.13		1.20	1.26

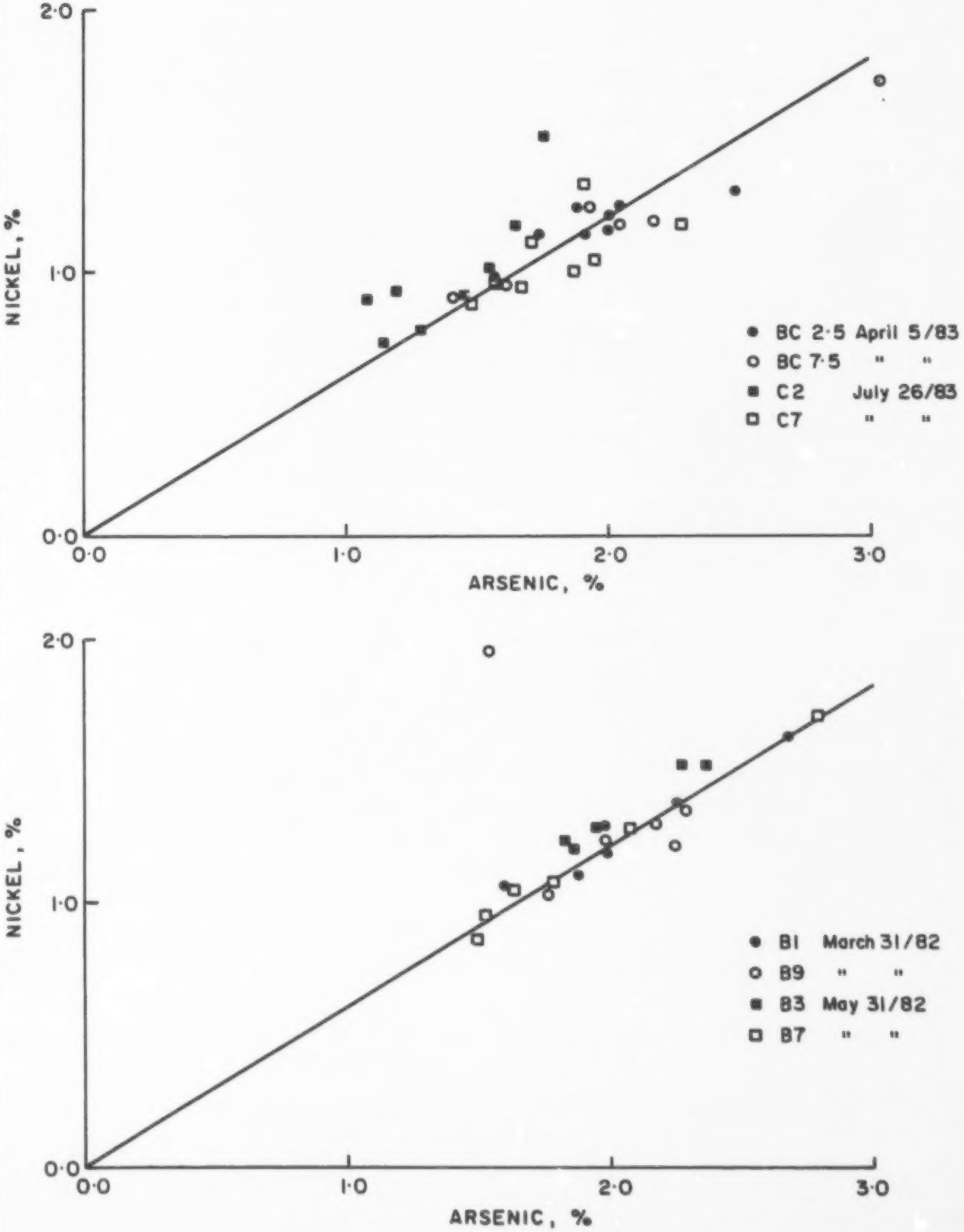

FIGURE 7·3 CORE SEGMENT NICKEL vs ARSENIC

A relative deficiency of uranium in the upper portion of the bed was first apparent in the July 26, 1982 samples and persisted thereafter. It is uncertain whether depletion of the upper portion has actually occurred or whether the earlier tailings were higher in uranium.

7.5.4 Distribution of Radium

Radium content of the core segments are provided in Appendix N. Radium content of the core as a function of bed depth was examined by averaging the radium measurement at regular depth. The results are presented in Table 7.9.

TABLE 7.9

B C Cores

Depth (cm)	Radium (pCi/g)
0-6	2770
6-12	3021
12-18	3237
18-24	3552
24-30	3010
30-36	3175
36-42	2980
42-48	2824
48-56	2898

G H Cores

Depth (cm)	Radium (pCi/g)
0-5	3870
5-10	4080
10-15	3501
15-20	4879
20-25	4365
25-30	4859
30-35	4332
35+	3746

No trend of radium concentration with depth is apparent.

ORI

Radium concentration in the core is strongly correlated with the fraction of fine material. This is illustrated in Figures 7.4 and 7.5 wherein radium assays from July 26, 1983 and January 16, 1984 cores are plotted against percent passing 12 micron size. As noted in section 7.1.4, the discharge side of the tailings contains a higher fraction of fine material, and the higher radium assays of the G/H core follow (Table 7.9).

Radium analyses on sized fractions of the upper, middle, and bottom thirds of core (January 16, 1984) provide the following data:

	Radium pCi/g		
Micron Size	+74	-74 + 12	-12
Depth			
Upper	1120	2383	11947
Middle	1051	2559	11949
Bottom	714	2005	11470

The higher concentration in the fines is very marked. The lower analyses afforded by the bottom third may have been caused by an inadvertent inclusion of bedding sand in the samples.

There is also a tendency for radium concentrations in the same size fraction to increase across the bed from the feed end to the beach end as illustrated below.

Micron	Radium pCi/g				
Size	B1.5, B8.5	B5	E5	H1.5, H8.5	J5
+74	827	705	1,041	1,103	1,675
74x12	2,236	2,001	2,128	2,397	2,775
-12	10,222	11,492	13,293	13,356	14,481

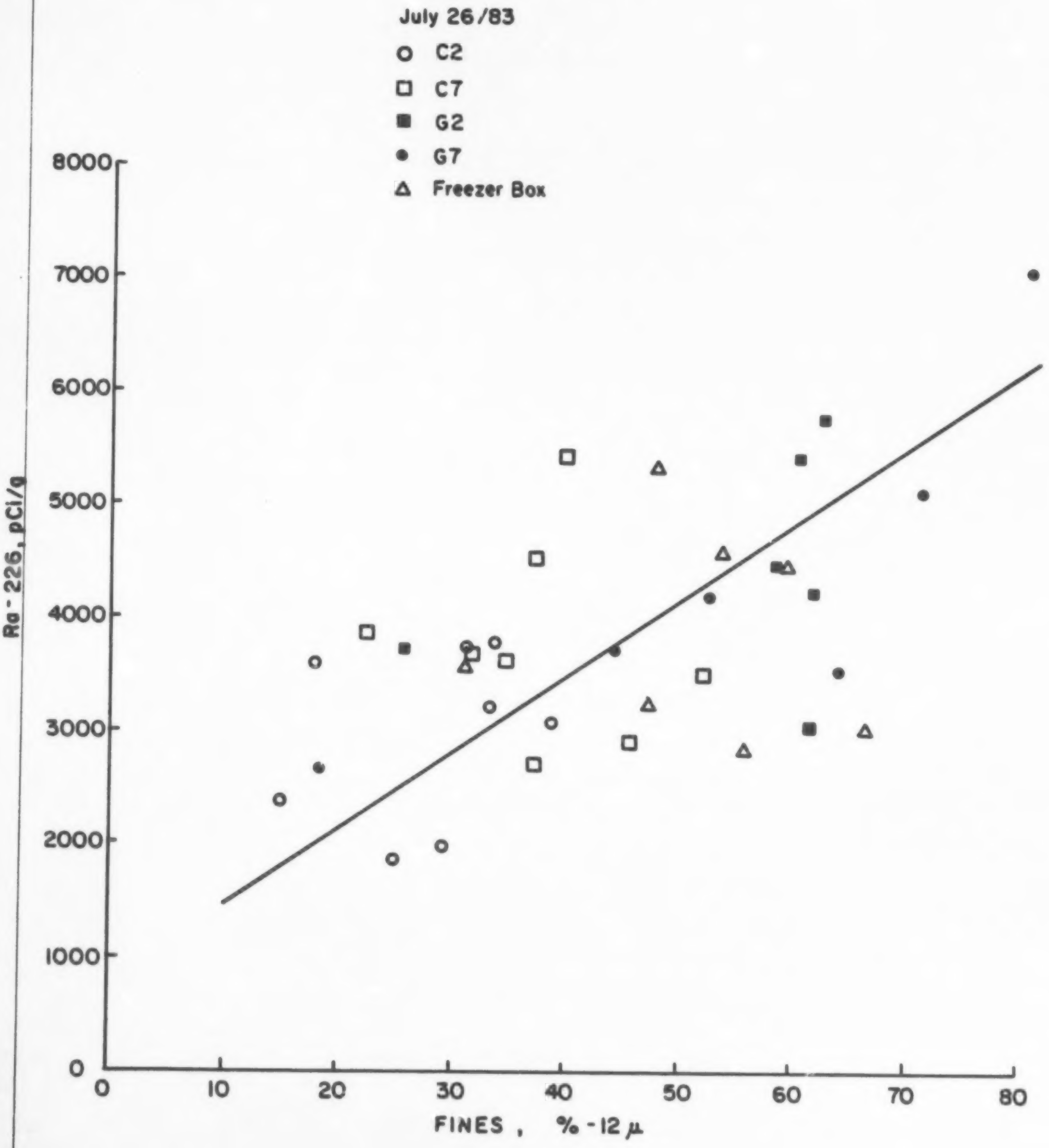

FIGURE 7·4 TAILING CORE SEGMENT RADIUM ASSAYS vs MINUS 12 MICRON CONTENT OF SEGMENT.

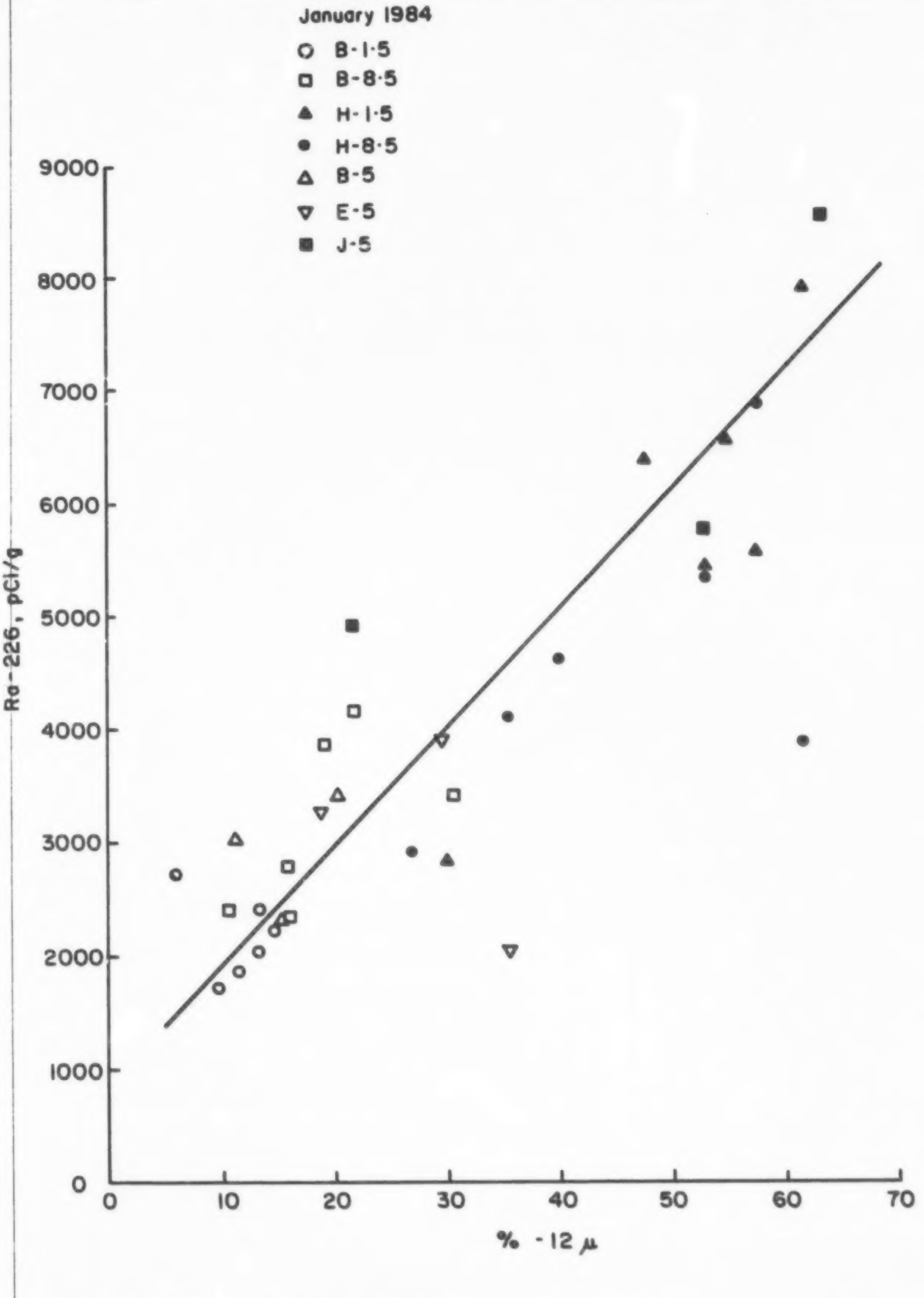

FIGURE 7·5 CORE RADIUM vs % MINUS 12 μ

7.5.5 Distribution of Other Elements

Analytical results are provided in Appendix O. Average core analysis (Table 7.10) show Fe, Ca, and Mg to be much higher at the discharge side than feed side. These elements exist largely as precipitates formed during liming, which, along with other fine material, were preferentially deposited downslope, i.e. the discharge side.

TABLE 7.10

	Feed Side (%)			Discharge Side (%)		
	July/82	Jan./83	July/83	July/82	Jan./83	Apr./83
Fe	0.69	0.78	0.82	1.41	1.38	1.54
Ca	5.60	5.69	5.07	11.5	11.0	12.3
Mg	0.21	0.22	0.21	0.39	0.38	0.41
K	0.44	0.50	0.68	0.73	0.38	1.07
Na	<0.1	0.08	0.16	<0.1	0.03	0.18
SO_4 (total)	11.6	12.9	-	23.0	21.5	-
SO_4 (water sol.)	10.6	11.1	-	20.5	17.7	-

A downwards migration of Ca, Mg, K, and Na is indicated in the assays of C2 core segments (July 26, 1983) in Table 7.11. From examination of other core segments, it is doubtful that iron migration is occurring.

TABLE 7.11
ANALYSIS OF CORE C2 SEGMENTS

Core Segment	Element (%)				
	Fe	Ca	Mg	K	Na
Top 1	0.64	2.86	0.14	0.43	0.11
2	0.74	3.96	0.19	0.71	0.11
3	0.85	4.30	0.21	0.75	0.14
4	0.83	5.12	0.20	0.67	0.15
5	0.98	5.10	0.22	0.69	0.16
6	0.70	6.27	0.22	0.58	0.15
7	0.81	5.46	0.25	0.80	0.16
Bottom 8	1.01	7.52	0.28	0.82	0.33

7.5.6 Freeze-Thaw Core

An examination of the analytical data for the core extracted on July 26, 1983 (Appendix N) indicates that the distribution patterns for arsenic, nickel, uranium and radium in the freeze-thaw section are similar to those in cores extracted from other areas of the bed.

The distribution of other elements within the freeze-thaw core is presented in Tables 7.12 and 7.13. The results obtained on core C2, extracted at the same time, are also presented. While direct comparison of the two cores is not possible since they come from different areas along the length of the bed, the depletion of cations in the upper portion of the bed, as noted in section 7.5.5, is evident in the freeze-thaw core, although not to the same extent.

TABLE 7.12

THE DISTRIBUTION OF Fe, Ca, Mg, K AND Na WITH DEPTH

Core Grid Position	Normal Bed Position C2 Element %					Freeze-Thaw Bed Element %				
	Fe	Ca	Mg	K	Na	Fe	Ca	Mg	K	Na
Top 1	0.64	2.86	0.14	0.43	0.11	1.03	5.23	0.21	0.57	0.08
2	0.74	3.96	0.19	0.71	0.11	1.41	10.65	0.34	0.63	0.08
3	0.85	4.30	0.21	0.75	0.14	1.06	8.14	0.31	0.87	0.09
4	0.83	5.12	0.20	0.67	0.15	1.14	12.35	0.38	0.91	0.23
5	0.98	5.10	0.22	0.69	0.16	1.06	10.6	0.35	0.8	0.20
6	0.70	6.27	0.22	0.58	0.15	0.95	7.63	0.35	1.12	0.27
7	0.81	5.46	0.25	0.80	0.16	1.29	10.99	0.39	1.05	0.21
Bottom 9	1.01	7.52	0.28	0.82	0.33	1.53	16.48	0.50	0.83	0.30

TABLE 7.13

THE DISTRIBUTION OF Cl, SO_4'', CO_3'' and HCO_3' IN CORES EXTRACTED FROM THE NORMAL BED AND FROM THE FREEZE-THAW BED

Core Segment	Chloride (mg/g)		Sulphate (mg/g)		Carbonate (mg/g)		Bicarbonate (mg/g)	
	Core C2	Freezer	Core C2	Freezer	Core C2	Freezer	Core C2	Freezer
T 1	<0.1	<0.1	98.9	65.7	2.5	<0.1	18.2	11.7
2	<0.1	<0.1	159	83.2	15.4	<0.1	54.6	24.2
3	<0.1	<0.1	148	96.6	5.5	<0.1	47.8	21.5
4	<0.1	<0.1	223	109	12.8	<0.1	63.6	29.7
5	<0.1	<0.1	219	98.6	21.5	0.84	43.4	38.1
6	<0.1	0.2	125	103	24.0	8.64	24.0	44.1
7	<0.1	0.3	167	77.6	21.8	11.2	21.8	41.7
B 8	<0.1	<0.1	227	123	64.6	11.8	64.6	53.7

The levels of sulphate, carbonate and bicarbonate are considerably lower in the freeze-thaw core. Depletion is evident in the upper levels, particularly in the case of carbonate.

Radium analysis on sized fractions of the freeze-thaw core extracted on January 16, 1984 are shown in Table 7.14. Although there appears to be an anomaly in the relative radium levels, higher radium concentrations again occur in the finer fractions.

TABLE 7.14
RADIUM ANALYSES ON FREEZE-THAW CORE TAKEN JANUARY 16, 1984

	Ra-226 (pCi/g)		
Core Segment	Whole Core	+74 micron Fraction	-74 micron Fraction
Top	3841	913	1867
Mid-section	4053	787	1652
Bottom	3980	1152	1706

7.6 X-Ray Diffraction (XRD) Analysis of Cores (Refer Appendix P)

XRD analysis of sized fractions of top, middle and bottom tailings core sections detected the following crystalline phases:

Quartz - SiO_2
Illite - $KAl_2(SiO_3AlO_{10})(OH)_2$
Chlorite - $(Mg, Fe)_2Al_3(Si_4O_{10})(OH)_8$
Bassanite - $CaSO_4.1/2H_2O$
Ferric Arsenite - $Fe_3(AsO_4)2.6H_2O$

ORF

TABLE 7.15

XRD ANALYSIS* OF JANUARY 16, 1984 CORE

	B1.5					B5					E5				
Core	**Q**	**I**	**C**	**B**	**Fe**	**Q**	**I**	**C**	**B**	**Fe**	**Q**	**I**	**C**	**B**	**Fe**
Top															
+74 m	2.07	-	-	-	-	1.73	-	-	0.67	-	1.77	-	-	-	-
74x12	1.47	-	-	-	-	1.45	-	-	0.67	0.67	1.26	-	-	-	-
-12	0.32	0.70	1.01	-	2.35	0.26	1.88	1.53	0.67	2.32	0.28	0.86	1.18	-	0.41
Middle															
+74 m	1.60	-	-	-	-	1.86	-	-	0.91	-	1.58	-	-	1.08	-
74x12	1.41	-	-	-	0.44	1.28	-	-	0.91	-	1.67	-	-	1.08	-
-12	0.11	1.62	1.00	-	1.04	0.24	0.93	0.86	0.91	1.38	0.32	0.83	0.95	1.08	0.61
Bottom															
+74 m	1.82	-	-	-	-	1.65	-	-	0.86	-	1.33	-	-	0.86	-
74x12	1.15	-	-	-	-	1.33	-	-	0.86	-	1.58	-	-	0.86	-
-12	0.30	0.97	1.01	0	1.02	0.11	1.04	0.57	0.86	1.25	0.21	0.78	0.71	0.86	1.25

	H1.5					H8.5					J5				
Core	**Q**	**I**	**C**	**B**	**Fe**	**Q**	**I**	**C**	**B**	**Fe**	**Q**	**I**	**C**	**B**	**Fe**
Top															
+74 m	1.45	-	-	1.14	-	1.56	-	-	-	-	1.11	-	-	0.97	-
74x12	1.33	-	-	1.14	-	1.47	-	-	-	0.31	1.45	-	-	0.97	-
-12	0.38	0.80	1.25	1.14	-	0.21	0.91	1.24	-	0.57	0.28	0.94	1.44	0.97	-
Middle															
+74	1.71	-	-	1.50	-	1.65	-	-	1.50	-	0.56	-	-	0.40	-
74x12	1.11	-	-	1.50	-	1.37	-	-	1.50	0.36	0.66	-	-	0.40	-
-12	0.11	1.96	1.04	1.50	-	0.32	0.86	0.75	1.50	-	0.28	0.89	0.93	0.40	-
Bottom															
+74 m	1.71	-	-	1.16	-	-	-	-	0.95	-	0.51	-	-	-	-
74x12	1.24	-	-	1.16	-	-	-	-	0.95	-	0.45	-	-	-	-
-12	0.30	0.86	0.69	1.16	-	0.30	0.95	0.95	0.95	-	0.32	0.19	0.90	-	-

Q = Quartz SiO_2
I = Illite $KAl_2(Si_3AlO_{10})(OH)_2$
C = Chlorite $(Mg,Fe)_2\ Al_3(Si_4O_{10})(OH)_8$
B = Bassanite $CaSO_4.1/2H_2O$
Fe = Ferric Arsenate $Fe_3(AsO_4)_2\ 6H_2O$

*Listings are concentrations relative to the average value for the particular species concerned.

Relative contents of these minerals are shown in Table 7.15. The results indicate that quartz, considered to be rather inert, predominated in the coarser fractions of the samples while illite, bassanite, chlorite and ferric arsenate were dominant in the minus 12 micron fractions. The units shown in Table 7.15 represent the relative value of peak heights produced by the XRD analysis.

7.7 Cation Exchange Capacity

Capacity of the bed material to exchange soluble cations was measured on the cores sampled January 16, 1984, using radioactive cesium. The results are presented in Table 7.16. The percent minus 12 micron material in the same sample is included in the table.

TABLE 7.16

EXCHANGE CAPACITY, meq/100 g

Core	Core Position						
Segment	B1.5	B5.0	B8.5	E5.0	H1.5	H8.5	J5.0
Top	5.95	7.00	9.53	11.14	21.20	15.77	21.27
Middle	7.58	6.79	14.69	14.69	23.17	21.62	6.66
Bottom	10.80	12.59	8.79	14.59	16.27	18.88	4.00

WEIGHT % PERCENT PASSING 12 MICRON SIZE

Core Segment	B1.5	B5.0	B8.5	E5.0	H1.5	H8.5	J5.0
Top	9.6	11.2	23.1	18.9	51.2	37.7	58.0
Middle	14.0	15.5	20.4	29.4	62.6	59.5	12.2
Bottom	10.6	20.2	13.4	35.6	42.8	39.9	2.9

Most of the exchange capacity is evidently confined to the fines material (see Figure 7.6).

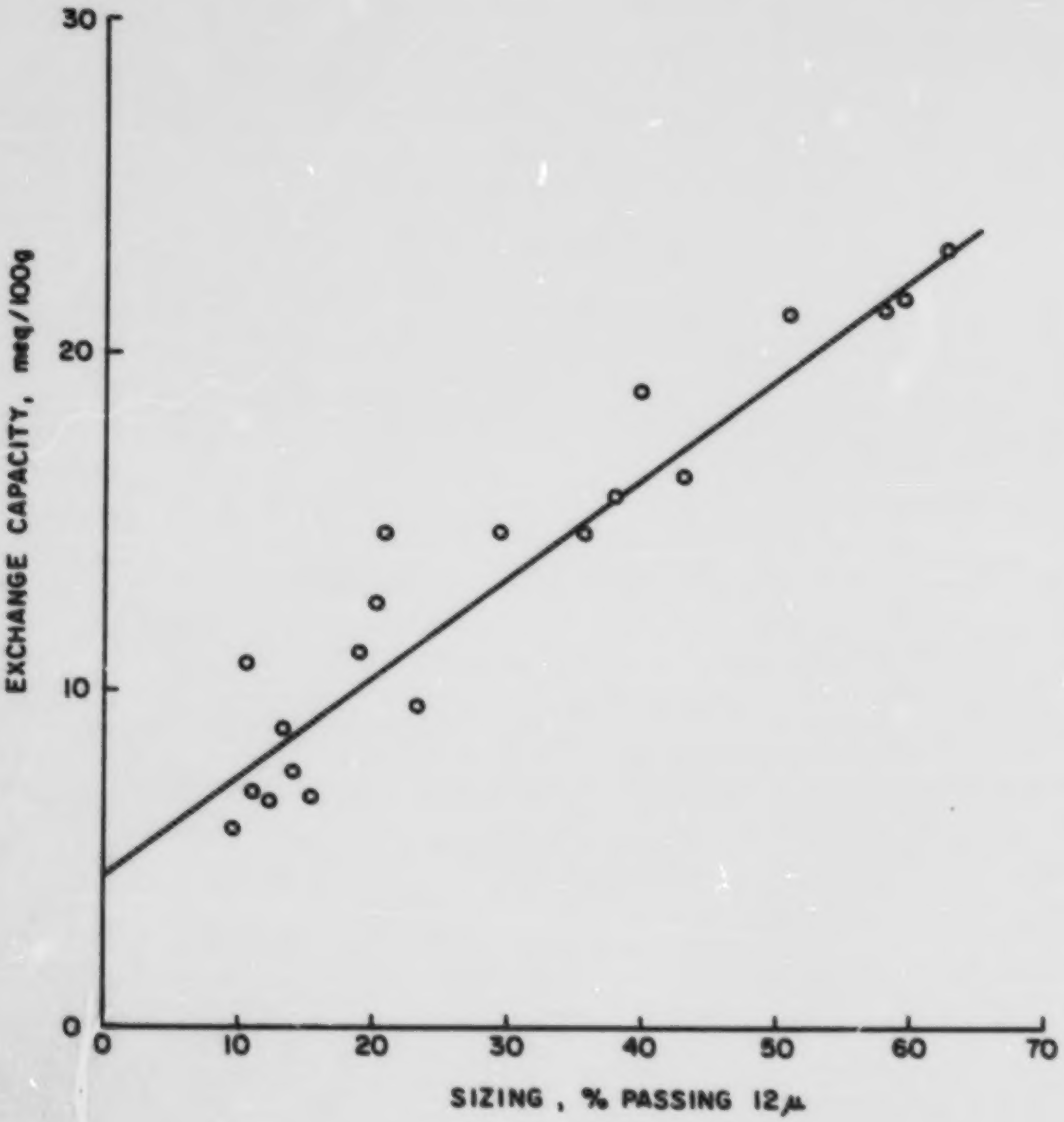

FIGURE 7·6 EXCHANGE CAPACITY OF TAILINGS

The results are consistent with data published by Grim,* who showed that both illite and chlorite, two clay group minerals present in the ore, have a cation exchange capacity (C.E.C.) of between 10 and 40 meq/100 g. Quartz has a C.E.C. of <10 meq/100 g. No minerals with a high C.E.C. (e.g. montmorillonite, C.E.C. >100 meq/100 g) were detected.

*Grim, R.E.: Clay Mineralogy, McGraw Hill, 1968.0

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APPENDIX A

TAILINGS PIT PERFORMANCE DURING
CANADA WIDE MINES LIMITED
CAMPAIGNS 1 AND 2
BASED ON KNIGHT AND PIESOLD REPORTS

1. Canada Wide Mines Ltd. - Campaign No. 1

1.1 General

Campaign No. 1 was run over approximately 22 days, with tailings reaching the storage area at 8:30 p.m. on November 26, and the system being shut down on December 17, after the placement of 5 layers of tailings.

Owing to on going mechanical and process difficulties in the pilot plant, the feed to the tailings area was highly variable in composition and flow rate and this precluded reliable monitoring of the facility for much of the campaign. A continuous and stable operation was maintained between December 12, and December 17, and from this period the official data for Campaign No. 1 has been compiled.

1.2 Water Recovery During Campaign No. 1 November 26 - December 11, 1981

During the application of the first layer of tailings over the sand filter blanket no runoff was recovered. Seepage recovery did not commence for several days as the quantities were small.

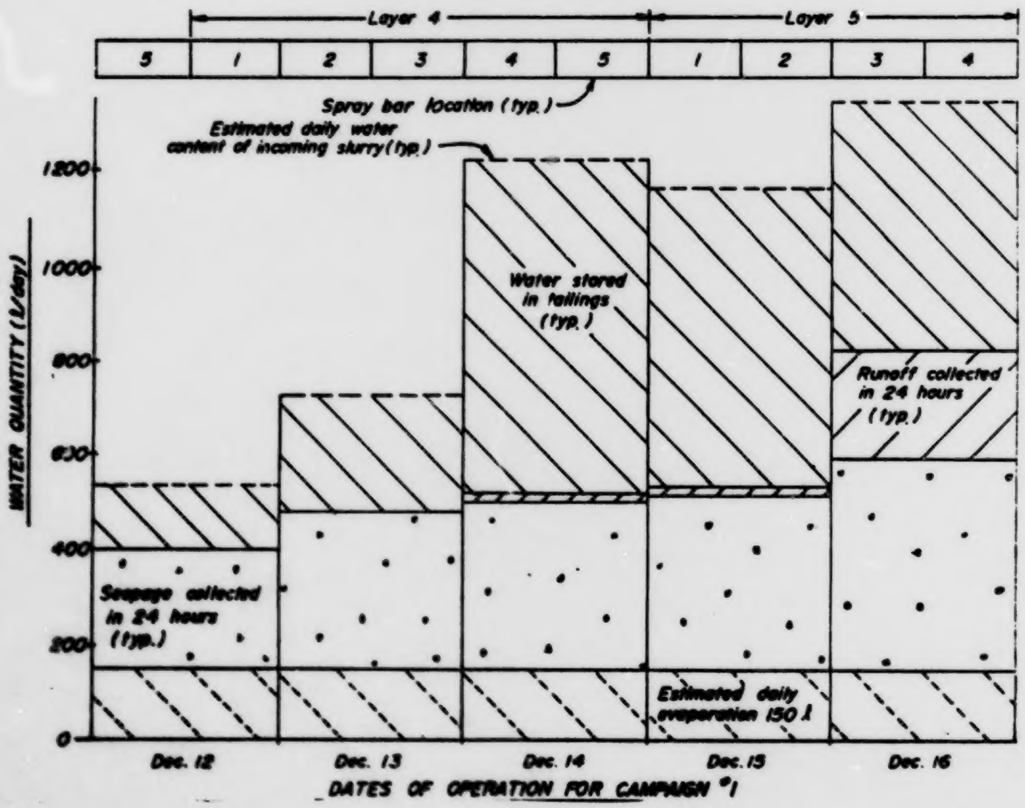
During subsequent layering of the tailings, small quantities of runoff began to be collected from the second layer. Seepage quantities increased and were significantly greater than runoff. During the application of these early layers of tailings, shrinkage cracking around the edges of the facility and through the tailings mass provided a preferential path for runoff to reach the filter blanket rather than flow to the drainage embankment. The filter blanket was not totally covered with tailings until the third layer was completed.

December 12 - 17, 1981

The pilot plant was briefly shut down before December 12, owing to upstream processing difficulties unrelated to the tailings pit. Between December 12 and 17 layers 4 and 5 were emplaced. During this period seepage quantities remained relatively high although towards the end of the campaign, runoff flows had increased significantly. This is illustrated in the following Figure 2.

FIGURE 2

AVERAGE WATER BALANCE - CAMPAIGN #1



1.3 Water Balance - Campaign No. 1

The water balance is shown in the following Table.

CAMPAIGN NO. 1 - WATER BALANCE DATA

Date:	December 12 to 17 (5 days)	
Vol. of Slurry Deposited:	5800 litres	
Dry Weight of Solids:	2076 kg	
Av. Solids Content of Slurry:	29.1%	
Estimated Pulp Density (Av):	1.22 kg/L	
Estimated Water in Slurry:	4995 L	
Total Seepage Collected:	1750 L	(35%)
Total Runoff Collected:	390 L	(8%)
Estimated Evaporation at 150 1/24 hrs:	750 L	(15%)
Estimated Water Stored in Tailings	2150 L	(42%)
TOTAL	4995 L	(100%)

Estimated Av. Moisture Content of Tailings: 101%

1.4 Water Balance Campaign No. 1 - Discussion

On the basis of data collected during this work the distribution of water incoming to the tailings facility can be expressed as follows:

Total incoming water	100%
Seepage	35%
Runoff	8%
Total Recovery	43%
Evaporation	15%
Retained in Facility	42%

NOTE: During this period no rain was introduced into the system.

The data obtained from Campaign No. 1 are in general agreement with that predicted theoretically, although total recovery was somewhat higher than expected and evaporation losses were somewhat lower than the model requirements. Campaign No. 1 was run under conditions of low evaporation, low solids content of incoming slurry and a total deposited tailings depth averaging only 200 mm when compared to the more favourable test conditions and 1000 mm thickness of tailings used to make theoretical predictions.

2. Canada Wide Mines Ltd. - Campaign No. 2

2.1 DEPOSITION OF MATERIAL IN THE TAILINGS POND

Campaign No. 2 saw the continuous operation of the pilot plant facility from 1:00 a.m. on January 26, until 4:00 p.m. on February 5 with a 2 day shutdown between January 30 and February 1. During this time tailings were deposited for approximately 9 days and the bed depth was increased into the 9th layer. In addition 9 "rainfall events" were initiated with 2 additional events being carried out in the two days after the tailings deposition had ceased.

Neither runoff nor seepage appeared from the tailings area until approximately 48 hours after tailings were first pumped to the facility. Flow from both sumps was observed only after the application of the first 500 L of rainfall. For the duration of the run both seepage and runoff quantities remained similar and together accounted for approximately 41% of the total water incoming from both the tailings slurry and from rainfall.

2.2 The Relationship Between Rainfall Events, Runoff and Seepage

The quantities of seepage and runoff collected from the three rainfall events were as follows:

	RAINFALL EVENT			TOTAL
	No. 1	No. 2	No. 3	
Rainfall added (L)	500	500	500	1500
Seepage collected (L)	6	22	30	58
Runoff Collected (L)	136	222	228	586
Deficit (L)	358	256	242	856
Time Between Rainfall (hrs)	-	20	23	43
Estimated evaporation (L)	210	240	-	450

These results show a very rapid increase and attenuation in the flow of runoff and seepage from a high intensity rainfall event, with flows reduced to a trickle within 6 hours.

These figures also indicate a significant deficit within the system. This can be accounted for by three factors: (i) evaporative losses, (ii) leakage

(Continued).... Campaign No. 2 - Water Balance Data

Parameter	Totals for Campaign Number 2	Adjusted Daily Rate For 9 Continuous Days of Operation *
Total Rainfall Added	5500 L	272 L/day
Runoff Collected	3323 L (24%)	217 L/day (18%)
Seepage Collected	2326 L (17%)	242 L/day (21%)
Total Water Collected	5649 L (41%)	573 L/day (39%)
Evaporation	2500 L (18%)	200 L/day (17%)
Water Not Accounted For (Assumed Retained in Tailings)	5476 L (41%)	516 L/day (44%)
Estimated Moisture Content	161%	136%

* Data has been adjusted by lowering the rainfall input and removing the excess from seepage, runoff and storage in the ratio 0.05:0.45:0.5 as established during subsequent experiment.

The adjustment re-establishes the ratio between average daily rainfall quantity and average daily solids production developed in the design report: Reference Document No. (i).

2.4 Evaporation During Campaigns 1 and 2

On the basis of data collected from the evaporation pans, the average surface area of the deposited tailings and a water mass balance, the following average evaporation rates have been used:

Campaign No. 1	150 litres/day
Campaign No. 2	200 litres/day
Experimental Rainfall	250 litres/day

2.5 Discussion of The Water Balance Attained During Campaign No. 1. and Campaign No. 2

On the basis of data collected during this work the distribution of water incoming to the tailings facility has been determined and is tabulated below together with the design data established in Reference Document No. (i), and data from the Model Tests (Reference Document No. (ii).

	Campaign #1 (a)	Campaign #2 (b)		Model Data Ref. 2 Initial Phase (a)	Design Data Phase IV B Ref. 1 (b)
		Unadjusted	Adjusted		
Total Incoming Water	100%	100%	100%	100%	100%
Seepage	35%	17%	21%	21%	21%
Runoff	8%	24%	18%	5%	22%
Total Recovery	43%	41%	39%	30%	43%
Evaporation	15%	18%	17%	30%	26%
Retained in Facility	42%	41%	44%	40%	31%

Notes:

(a) Excludes rain

(b) Includes rain

It will be noted that there was a levelling in the proportion of seepage and an increase in the runoff as the thickness of deposited tailings increased. There was insufficient time to lower, by evaporation, the water content of the tailings material to the desired state of consolidation and unsaturation. Consequently the filling of shrinkage cracks slowed the leakage of runoff into the underdrainage system. In the prototype, unsaturated and consolidated underlayers acted as temporary storage for the downward passage of any seepage front.

2.6 Characteristics of the Tailings Bed After Campaigns 1 and 2 Sampling Procudure

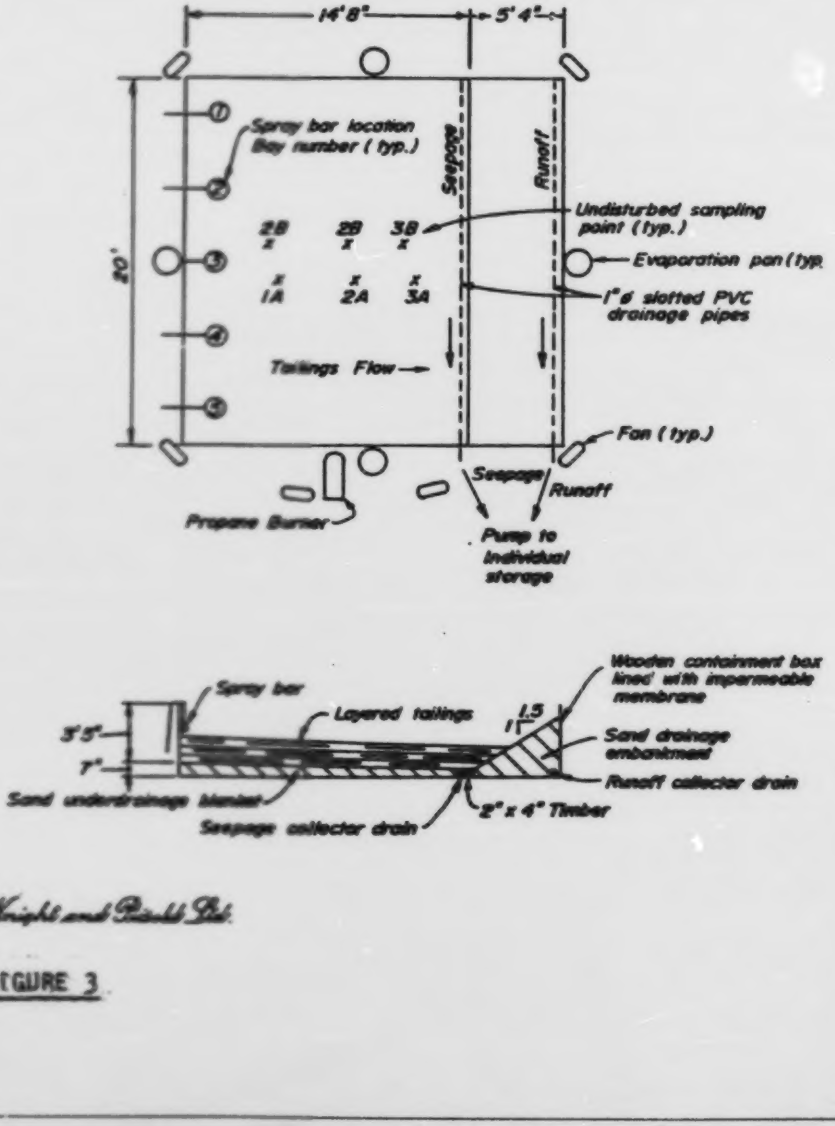
Ten days after the final layer was placed in Campaign No. 2 six undisturbed core samples were extracted from the bed in nominal 3 inch (7.62 cm) diameter thin walled steel Shelby tubes driven vertically downward and sealed with wax immediately after removal.

The cores were obtained from points located approximately 1/4, 1/2 and 3/4 of the way down the slope of the bed and midway between the edges. The sample designations and locations are summarized below and on Figure 3.

Sample Number	Core Length	Location (Distance from Upstream Wall)
1A	19" (480 mm)	4' 10" (1470 mm)
1B	19" (480 mm)	4' 6" (1370 mm)
2A	17" (430 mm)	9' 0" (2740 mm)
2B	16" (410 mm)	8' 6" (2590 mm)
3A	14" (360 mm	12' 2" (3710 mm)
3B	14" (360 mm	11' 4" (3450 mm)

The tubes were shipped to Vancouver for laboratory testing which included particle size distribution analyses, moisture content, density and Atterberg Limit determinations plus consolidation and permeability testing. Details of the testing and results obtained are summarized in the following sections.

GENERAL CONFIGURATION OF TAILINGS FACILITY


14'8"
5'4"
20'
①
②
③
④
⑤
Spray bar location
Bay number (typ.)
Seepage
Runoff
2B
2B
3B
1A
2A
3A
Undisturbed sampling point (typ.)
Evaporation pan (typ.
1" ø slotted PVC drainage pipes
Tailings Flow
Fan (typ.)
Seepage
Runoff
Propane Burner
Pump to individual storage
Spray bar
Layered tailings
1.5
1
Wooden containment box lined with impermeable membrane
3'5"
7"
Sand drainage embankment
Runoff collector drain
Sand underdrainage blanket
2" x 4" Timber
Seepage collector drain

Knight and Piésold Ltd.

FIGURE 3

2.7 Core Logs

Core logs were obtained from the undisturbed samples prior to further testing. A qualitative description of the cores is given below:

SAMPLE NO.	DESCRIPTION
1A	● Soft laminated sandy silt to silty sand tailings. Colour of layers range from pink to light brown to grey with yellows and occasional green pockets.
2A	● Very soft light brown to pink laminated sandy silt tailings with occasional yellow layers of sandy silt.
3A	● Very soft light brown grey to yellow layered sandy silt with occasional sand lenses.
1B	● See Figure 4 on next page.
2B	● Beige very soft fine sandy silt. See also Figure on next page.
3B	● Beige very soft find sandy silt. See also Figure 4 on next page.

The layering and heterogeneous nature of the tailings material is apparent from the log. Generally the material was observed to be very soft sandy silt to fine silty sand with a wide variation in colour.

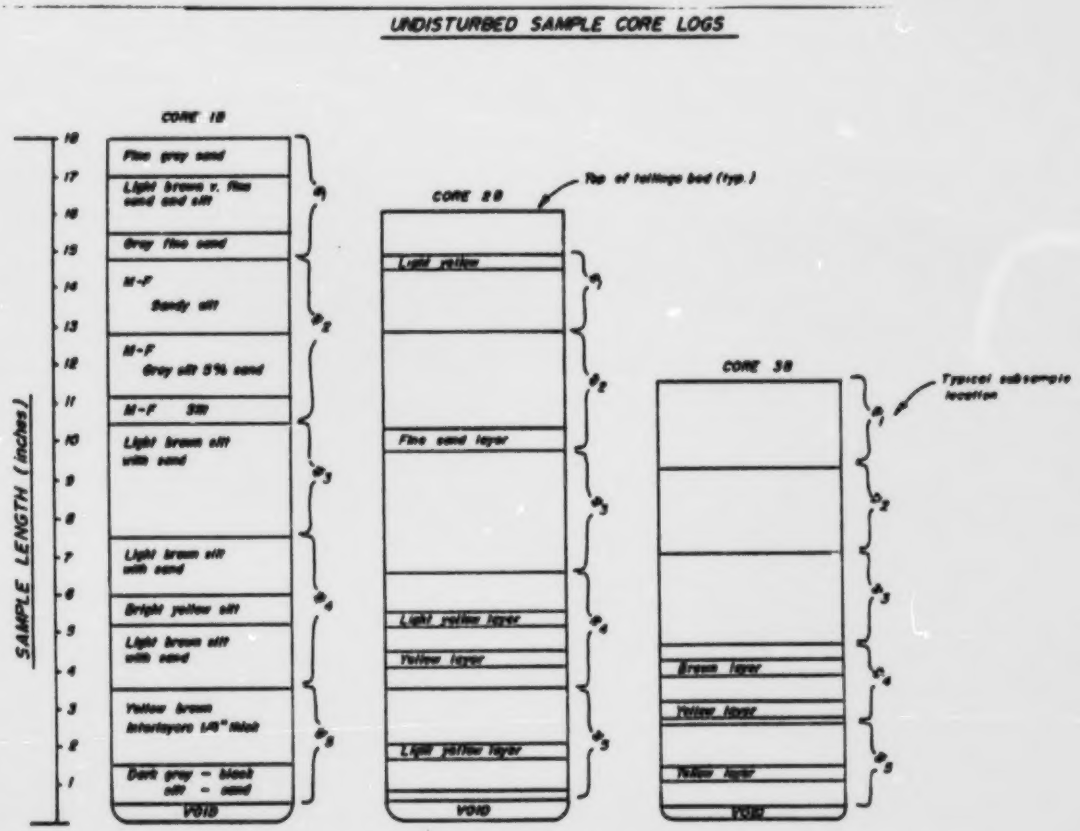

UNDISTURBED SAMPLE CORE LOGS
SAMPLE LENGTH (inches)
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
CORE 1B
Fine gray sand
Light brown v. fine sand and silt
Gray fine sand
M-F Sandy silt
M-F Gray silt 5% sand
M-F Silt
Light brown silt with sand
Light brown silt with sand
Bright yellow silt
Light brown silt with sand
Yellow brown interlayers 1/8" thick
Dark gray - black silt - sand
VOID
#1
#2
#3
#4
#5
CORE 2B
Top of tailings bed (typ.)
Light yellow
Fine sand layer
Light yellow layer
Yellow layer
Light yellow layer
VOID
#1
#2
#3
#4
#5
CORE 3B
Typical subsample location
Brown layer
Yellow layer
Yellow layer
VOID
#1
#2
#3
#4
#5

FIGURE 4: Diagram of undisturbed core logs.

2.8 Consolidation and Permeability

Core Samples 1A, 2A and 3A were consolidated in a triaxial cell and the coefficient of vertical permeability measured at two different confining pressures. The consolidation parameters and permeability results are summarized below:

MIDWEST PROJECT
PILOT PLANT TAILINGS FACILITY
PERMEABILITY TESTING ON UNDISTURBED SAMPLES

SAMPLE NO.	VOID RATIO	DRY DENSITY (t/m^3)	σ'_3 (kPa)	C_v (m^2/yr)	k (m/s)
1A	2.58	0.74	64.6	64.29	5×10^{-8}
	2.04	0.87	197.8	55.32	2×10^{-8}
2A	2.35	0.79	46.9	66.8	3×10^{-8}
	2.01	0.88	227.5	38.7	1.7×10^{-9}
3A	4.20	0.51	56.5	46.8	8.5×10^{-8}
	2.53	0.75	224.1	31.6	2.0×10^{-8}

Specific Gravity = 2.65

The coefficient of consolidation is fairly consistent for all samples ranging between 31.6 and 66.8 m^2/yr. The coefficient of vertical permeability varied from an average of 5.03 x 10^{-8} m/s at a confining pressure of 50 kPa to an average of 8.8 x 10^{-9} m/s at a confining pressure of 200 kPa.

2.9 DENSITY AND MOISTURE CONTENT

UNDISTURBED SAMPLES: DENSITY AND MOISTURE CONTENT

Sample Nos	Bulk Density (t/m^3)	Moisture Content (%)	Dry Density (t/m^3)
1A	1.31	90.2	0.69
2A	1.28	178.3	0.46
3A	1.25	154.7	0.49
1B-1 (Top)	1.32	118.3	0.60
2	1.44	94.0	0.74
3	1.42	109.1	0.68
4	1.34	125.9	0.59
5 (Bottom)	1.48	104.0	0.73
Average	1.43	110.3	0.68
2B - 1 (Top)	1.22	180.3	0.44
2	1.25	188.8	0.43
3	1.23	120.5	0.56
4	1.23	145.8	0.50
5 (Bottom)	1.33	126.3	0.59
Average	1.26	152.3	0.50
3B - 1 (Top)	1.31	168.7	0.49
2	1.30	209.1	0.42
3	1.31	187.1	0.46
4	1.32	180.3	0.47
5 (Bottom)	1.32	155.7	0.52
Average		180.2	0.48

Generally, there is a tendency for moisture content to increase and density to decrease as the sampling distance from the spray bar increases. The densities are generally lower than achieved in the previous laboratory and model tests, even after consolidation in the triaxial cells. The model tests indicated dry densities in the range of 1.0 to 1.1 t/m^2 at confining pressures of 150 kPa, whereas tests on the pilot plant material achieved an average dry density of 0.85 t/m^3 at 200 kPa. This could be accounted for in part by insufficient evaporation in the pilot facility but also indicates a basic variation in material characteristics, which is also reflected in the generally lower densities achieved by pure sedimentation.

2.10 Particle Size Distribution Analyses

Particle size distribution analyses were conducted on representative material from cores 1A, 2A and 3A. The results obtained are illustrated by Figure 5A on the following pages as are the analyses from specific layers in each of the cores numbered 1B, 2B, and 3B. Envelopes of these three sets of analyses are shown.

Figure 5B shows a clear segregation of the tailings material with the coarser leach residue settling out closer to the spray bars. This is seen to be relatively consistent throughout the two campaigns when comparing discrete samples from different layers at each location, as shown in Figure 5C, and by comparing the envelopes of these curves, as shown in Figure 5D.

Material near the top of the tailings beach is well graded with the silt, gypsum and metal hydroxides evenly distributed with the sand fraction. By contrast, Figure 5E shows a large percentage of material in the 10 micron range which is the effective floc size of the gypsum and metal hydroxides.

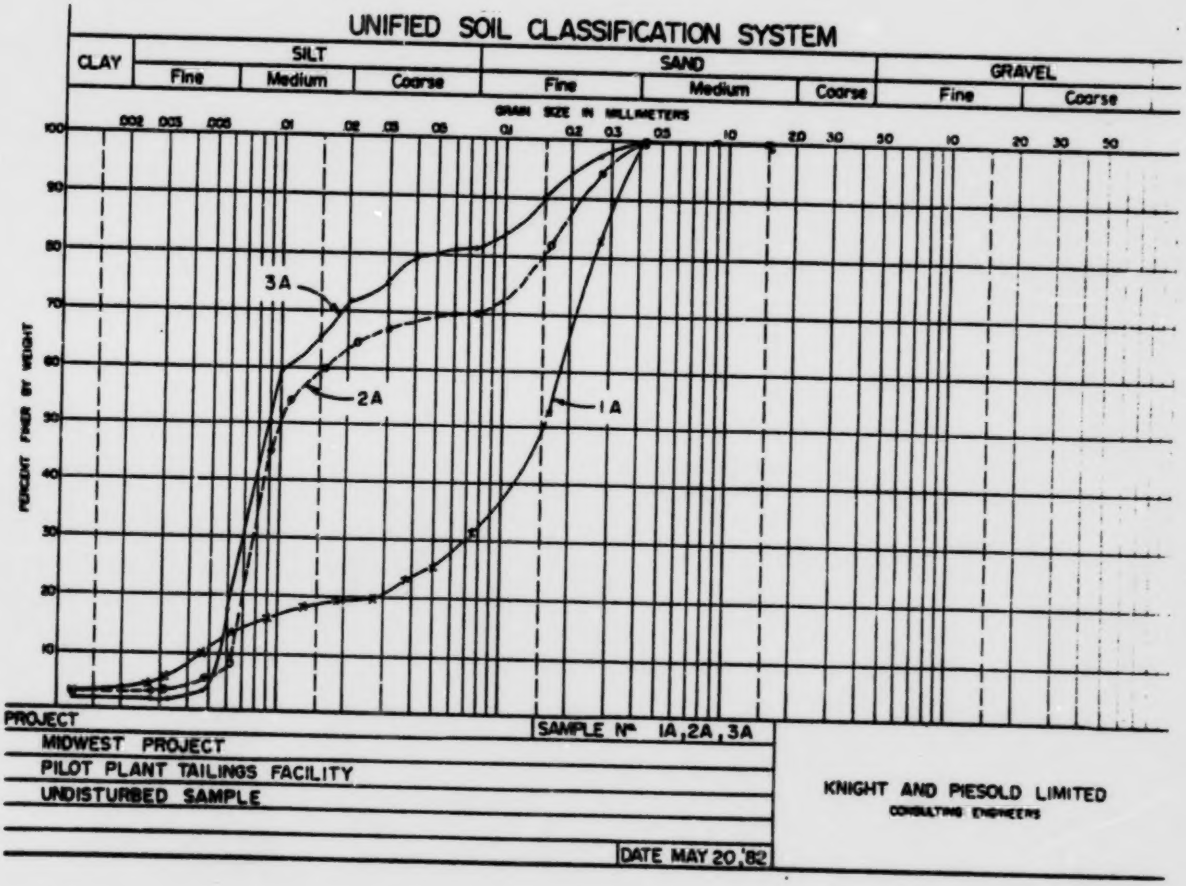


FIGURE 5A: Particle size distribution curve

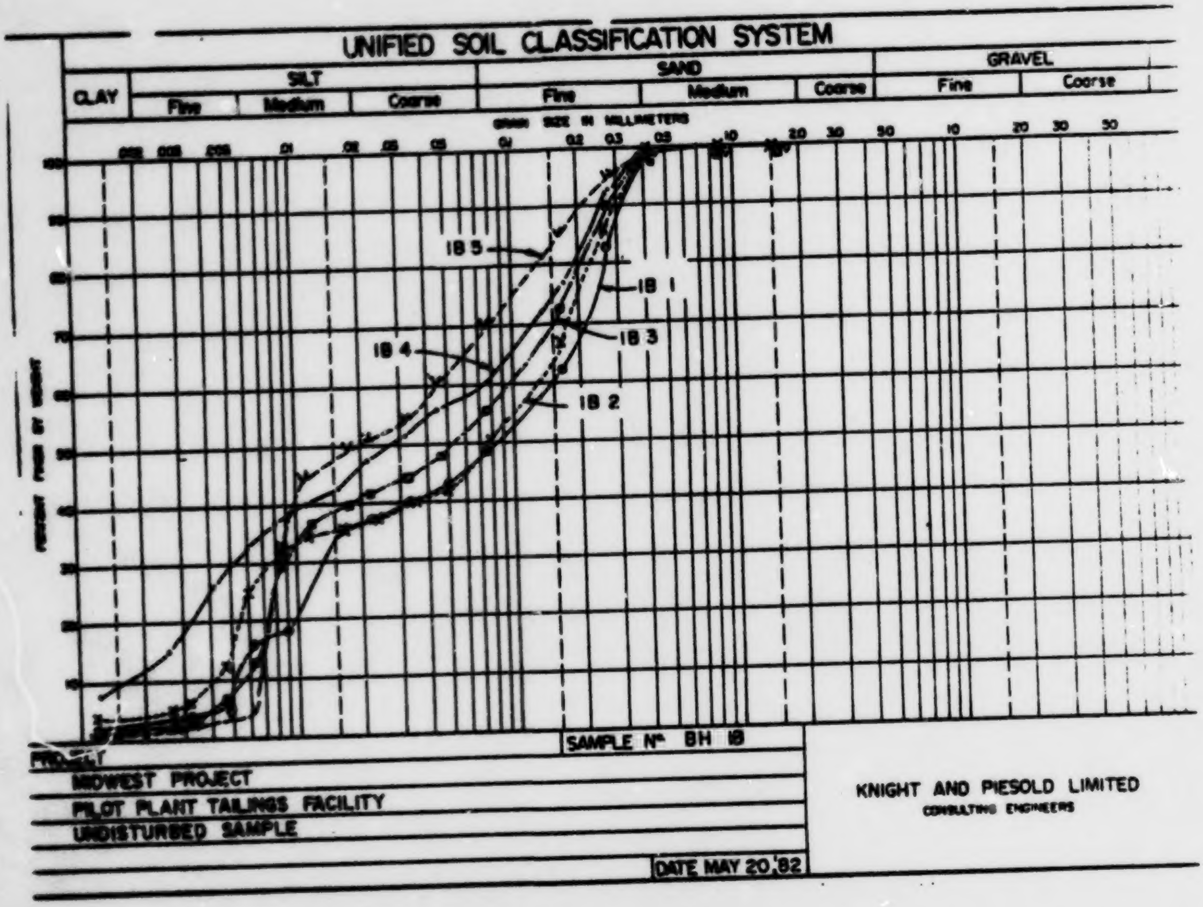
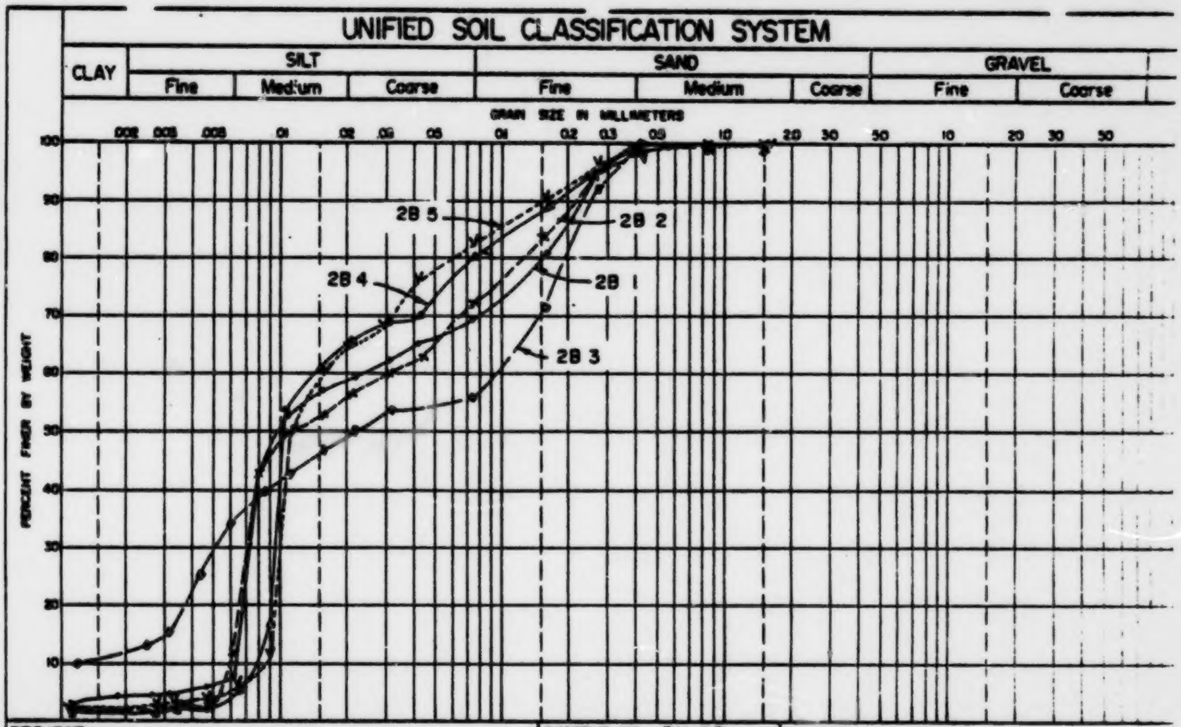


FIGURE 5B: Particle size distribution curve



PROJECT	SAMPLE Nº BH 2B	KNIGHT AND PIESOLD LIMITED CONSULTING ENGINEERS
MIDWEST PROJECT		
PILOT PLANT TAILINGS FACILITY		
UNDISTURBED SAMPLE		
	DATE MAY 20,'82	

FIGURE 5C: Particle size distribution curves

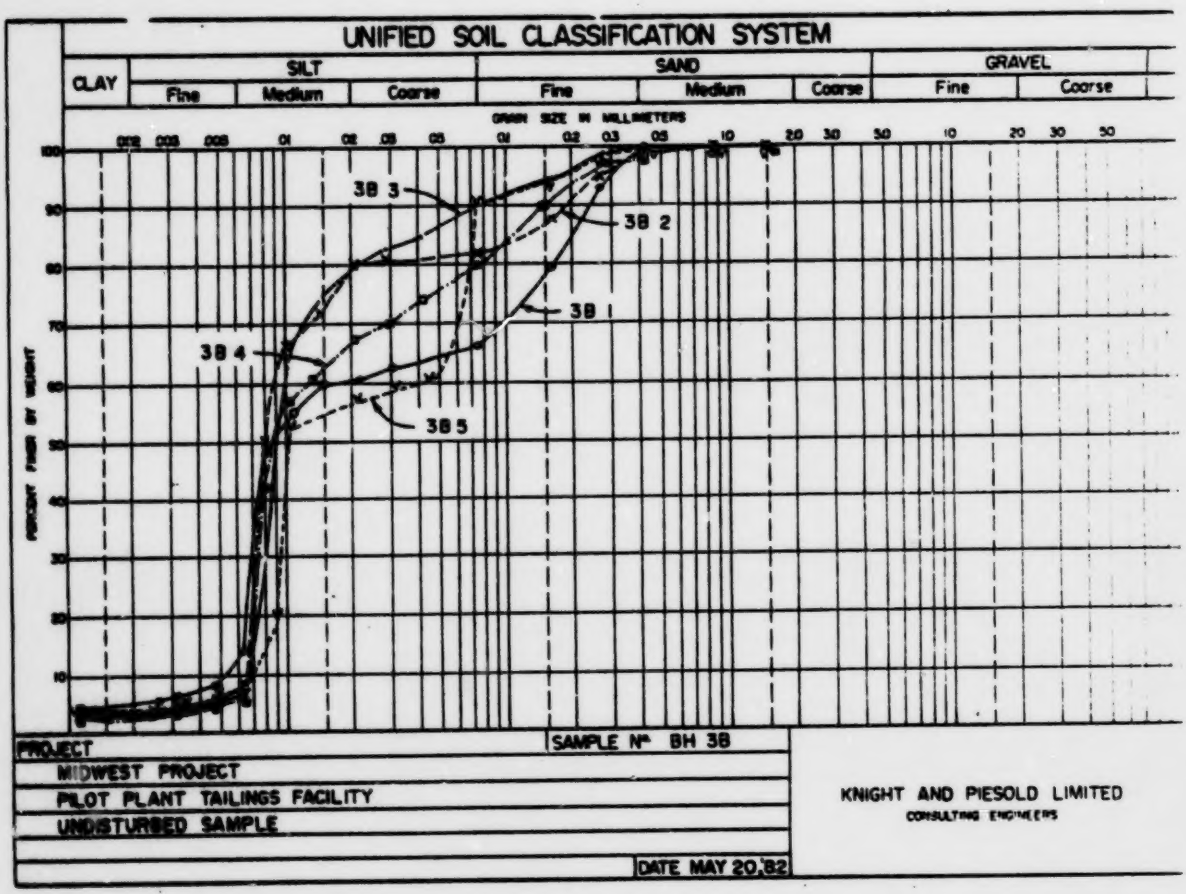


FIGURE 5D: Particle size distribution curves

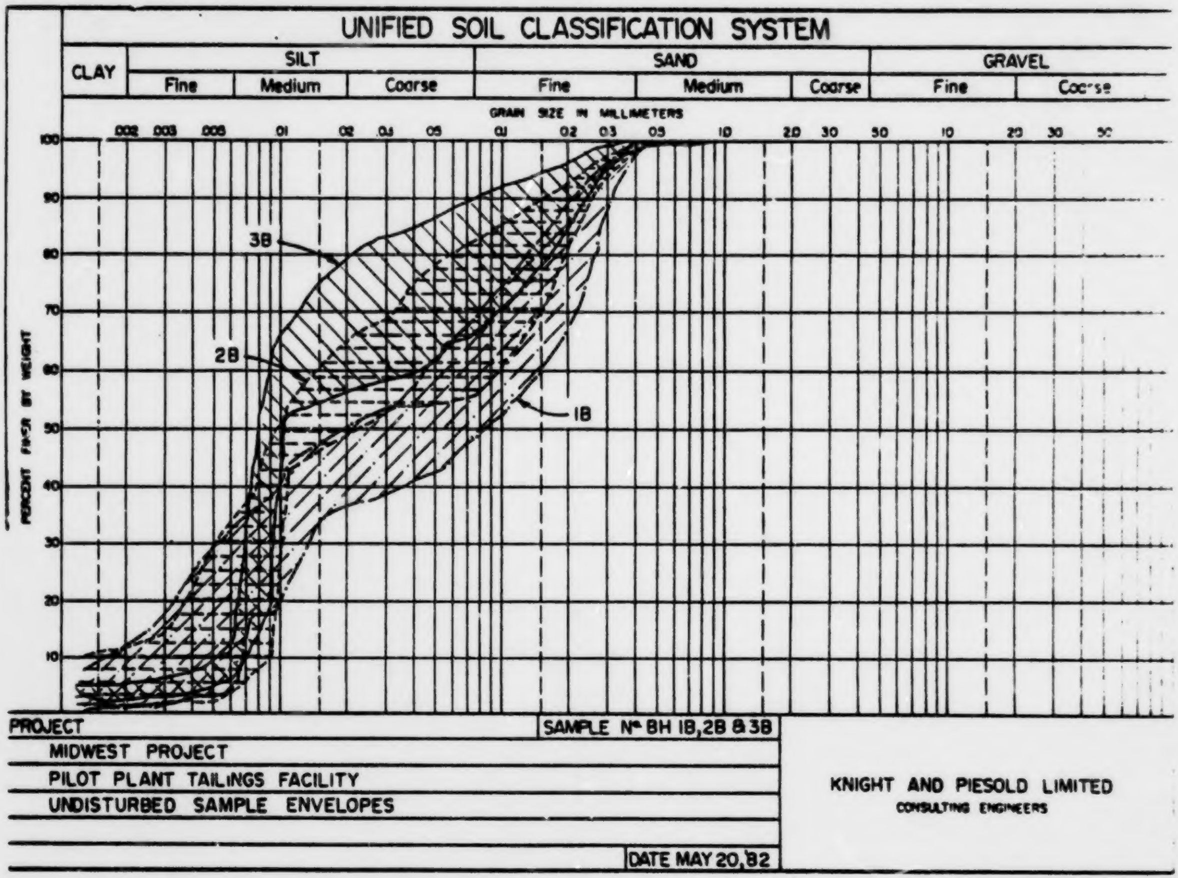


FIGURE 5E: Particle size distribution curves

2.11 ATTERBERG LIMITS

Atterberg Limits determined on samples taken from each core are given in the table below:

ATTERBERG LIMITS - UNDISTURBED SAMPLES

Sample	Liquid Limit	Plastic Limit	Plasticity Index
1 B1	48.9%	26.2%	22.7
1 B2	34.5%	22.7%	11.8
1 B3	62.6%	38.0%	24.6
1 B4	71.1%	44.5%	26.6
1 B5	77.1%	42.7%	34.4
2 B1	79.5%	47.5%	32.0
2 B2	86.0%	46.8%	39.2
2 B3	66.6%	42.7%	23.9
2 B4	97.0%	55.8%	41.2
2 B5	106.0%	60.7%	45.3
3 B1	56.6%	40.9%	15.7
3 B2	18.0%	49.3%	18.7
3 B3	77.1%	53.3%	23.8
3 B4	106.5%	65.1%	41.4
3 B5	106.2%	62.5%	43.4
1 A	34.8%	26.1%	8.7
2 A	67.0%	36.1%	30.9
3 A	95.7%	54.8%	40.9

The large variations in the Plasticity Index emphasises the variability of the tailings feed during the pilot program and resulting heterogeneous nature of the tailings deposit.

2.12 The Effect of Rainfall on Tailings Moisture Content

After tailings deposition was complete, systematic rainfall was initiated and use was made of the opportunity to investigate the effect of rainfall on the moisture content of the tailings. Data given in the Table below represents the average of three separate cores taken at 1/4, 1/2 and 3/4 points down the centre line of the bed. Cores were separated into layers and the individual moistures were determined. Moisture content is expressed as a percentage of dry weight.

EFFECT OF RAINFALL ON TAILINGS MOISTURE CONTENT

Date	Time	Average Moisture Content of Tailings Material		
		Total	Top Layer	Bottom Layer
Feb. 15	5:00 a.m.	135%	157%	116%
15	11:30 a.m.	RAIN EVENT		
15	5:00 p.m.	135%	148%	117%
15	8:00 p.m.	142%	183%	127%
Feb. 16	11:30 a.m.	134%	170%	103%
16	12:00 a.m.	RAIN EVENT		111%
16	1:30 p.m.	134%	168%	116%
16	4:45 p.m.	131%	177%	117%
16	7:00 p.m.	138%	178%	123%
Feb. 17	10:00 a.m.	138%	179%	123%
17	11:30 a.m.	RAIN EVENT		
17	12:15 a.m.	150%	195%	127%
17	4:15 p.m.	142%	184%	118%

It can be seen that moisture content of the tailings material is slightly increased in the top and bottom layers after a rainfall event.

2.13 Radon Flux of the Tailings Bed
Observations

Thirteen readings of radon flux from the tailings surface were made with values ranging between 700 pCi/m^2/S and 5100 pCi/m^2/S. The average flux was 1900 pCi/m^2/S on the basis of observations made.

The results are summarized below:

TABLE OF RADON OBSERVATIONS
Campaign 1 & 2 (C.W.M.L.)

Date	Bay	Layers of Tailings	Moisture Content (% dry wt.) Surface	Moisture Content (% dry wt.) Average	No. of Observations	Radon Flux, pCi/m^2/S
26/1/82	#5	6	77.5%	N/A	1	2716
27/1/82	#1	6	N/A	80.8%	3	697-1196
28/1/82	#1	7	N/A	68.1%	3	1163-1422
28/1/82	#1	7	60.8%	66.9%	3	1601-1997
3/2/82	#2	8	67.4%	72%	3	2014-5132

There is some evidence for an increase in Radon flux as the moisture content of the bed was decreased. This is best exemplified by the three readings taken in Bay 1, from the same general location and after approximately 12 hour increments of drying. However, due to the highly variable composition of the tailings slurry and the use of the tailings facility as a disposal area for process spillages, variations in flux are probably also influenced by the local tailings composition.

Canada Centre for Mineral
and Energy Technology
Final Report

APPENDIX B

PILOT PLANT
SAMPLING STATION SUMMARY AND
SAMPLING PROCEDURES

CTC 1 SAMPLING STATIONS

SAMPLE STATION	NAME
2-3	Leach Feed Solids
3-3	Leach Discharge Solids
13-1	#5 Thickener Underflow Filtrate
13-3	#5 Thickener Underflow Solids
19-G	Clarified Pregnant - Grab
19-C	Clarified Pregnant - Shift Composite
21-G	Raffinate - Grab
21-C	Raffinate - Shift Composite
25	Pregnant Strip Liquor
26	Barren Strip Liquor
40	Drum Filter Filtrate
43	Effluent Sand Filter Discharge
46-1	Neutralized Tailings Filtrate
46-3	Neutralized Tailings Solids
47	Tailings Runoff
48	Tailings Seepage

CANMET TAILINGS CAMPAIGN #1

SAMPLING STATION SUMMARY

SAMPLING STATION #	NAME	TYPE	FREQUENCY	SAMPLE VOL(L)	NATURE	ANALYSE FOR	COMMENTS
2-3	Leach Feed Solids	Batch	Every Batch	0.5	Slurry	U, As, Ni, Co, Fe (Solids)	Dip Sample - Keep Solids Only
3-3	Leach Discharge Solids	Batch	"	0.5	Slurry	U, As, Ni, Co, Fe (Solids)	"
13-1	#5 Thickener U/F Filtrate	Shift Composite	Every 4 hours	1.0	Slurry	U, As, Ni, D^{226}Ra (Filtrate)	Collect & Combine Sample every 4 hrs, filter at shift end for shift composite
13-3	#5 Thickener	Shift Composite	"	1.0	Slurry	U, As, Ni, T^{226}Ra	Residue From previous filtration
19-G	Clarified Pregnant	Grab	"	0.10	Solution	U	Analyse on priority basis
19-C	Clarified Pregnant	Shift Composite	"	0.075	Solution	U, TSS, pH, Redox	Collect sample every 4 hrs & combine the 3 samples for shift composite
21G	Raffinate	Grab	"	0.10	Solution	U	Analyse on priority basis
21C	Raffinate	Shift Composite	"	0.50	Solution	U, As, T^{226}Ra, pH	Collect sample every 4 hours & combine the 3 samples for shift composite
25	Pregnant Strip Liquor	Shift Composite	"	0.075	Solution	U	"
26	Barren Strip Liquor	Shift Composite	"	0.075	Solution	U	"

CANMET TAILINGS CAMPAIGN #1

SAMPLING STATION SUMMARY

SAMPLING STATION #	NAME	TYPE	FREQUENCY	SAMPLE VOL(L)	NATURE	ANALYSE FOR	COMMENTS
40	Drum Filter Filtrate	Shift Composite	Every 4 hours	1.0	Solution	U, As, Ni, TSS, pH D^{226}Ra	Collect sample Every 4 hours & combine the 3 samples for shift composite
43	Effluent sand Filter Discharge	Shift Composite	"	1.2	"	U, As, T^{226}Ra, pH D^{226}Ra,	"
46-1	Neutralized Tailings Filtrate	Shift Composite	"	1.5	Slurry	U, As, Ni, D^{226}Ra pH (Filtrate)	Collect & combine sample every 4 hours, filter at shift end for shift composite
46-3	Neutralized Tailings Solids	Shift Composite	"	1.5	Slurry	U, As, Ni, T^{226}Ra Solids	Residue from previous filtration
47	Tailings Runoff	24 hour Composite	"	0.50	Solution	As, Ni, T^{226}Ra,pH	Collect sample every 4 hours and combine the 6 samples for day composite
48	Tailings Seepage	24 hour Composite	"	0.50	Solution	As, Ni, T^{226}Ra,pH	"

CANMET TAILINGS CAMPAIGN (CTCI)
SAMPLING SUMMARY

Bottle sizes in oz - Write assays required on label

G = 4 hour grab sample

C = Shift or (*) Day composite sample

R = Bottle to be Nitric Acid + Distilled water rinsed

F = -.45µ Filtrate

N = Sample to be Acidified with Nitric Acid (5 mL HNO_3/100 cc Solution)

H = Sample to be Acidified with Hydrochloric Adid (5 mL HCl/100 cc Solution)

SAMPLE STATION #	ORIGINAL SAMPLE BOTTLE	ASSAYS	SPLIT SAMPLES					
			BOTTLE SIZE	ASSAYS	BOTTLE SIZE	ASSAYS	BOTTLE SIZE	ASSAYS
4 HOUR GRAB SAMPLES - 8:00, 12:00, 16:00, 24:00								
9G	4	U						
21G	4	U						
SHIFT COMPOSITE SAMPLES (SAMPLED EVERY 4 HOURS DURING EACH SHIFT)								
2-3(res)	16	U,As, Ni, Co, Fe						
3-1	8	pH,Redox, Vol.						
3-2	4	vol.						
3-3(res)		U						
13-1	160 R,F,N	D.Ra^{226}	4	U, As, Ni				
13-3(res)		U,As, Ni, T.Ra^{226}						
19C	8	pH, U	8	TSS				
21C	160 R,N	pH,Redox, T.Ra^{226}	4	U, As				
25	8	U						
26	8	U						
40	160 R,F,N	pH, D.Ra^{226}	4 F,H	U, As, Ni	8	TSS		
43	160 R,N	pH, T.Ra^{226}	160 R,F,N	D.Ra^{226}	8 F, H	U, As		
46-1	160 R,F,N	pH, D.Ra^{226}	4 F,H	U, As, Ni				
46-3(res)		U, As, Ni, T.Ra^{226}						
47*	160 R,N	pH, T.Ra^{226}	4 F,H	As, Ni				
48 *	160 R,N	pH, T.Ra^{226}	4 F,H	As, Ni				

* NOTE: Do splits and pH before acidfying original sample

LABELLING INSTRUCTIONS

Label each and every sample fraction (Solution, Wash or Residue) with its own A # and description:

i.e.

A # is taken from sample record book

CTC 1 - ____ - ____ -day/month/time (0-2400 hours)

CANMET Tailings
Campaign #1

Sampling
Station
No.

Usually time of shift end

Sample Fraction:

1 = Neat (undiluted) solution
2 = Wash solution
3 = Residue

* Place the assays required for each sample on its label.

SAMPLING INSTRUCTIONS

Sampling Station #2

Name - Leach Feed (Solids)

Procedure
- For each sample (1), log an A# with description (including BATCH #) in Sample Record Book
- Label a 16 oz plastic bottle with the sample description
- Autoclave feed will be sampled each batch and submitted to the lab
- get slurry weight and volume and record on proper sheet
- Filter slurry on an 18.5 cm #541 paper (sample before acid additio
- Place entire cake in oven at 100°C for 4 hours or until dry.
- Get dry cake weight and record.
- Cut a representative sample of the cake and grind to -100 mesh for analysis, and bag with label CTC1-2-3-day/month/time, Batch #, and A#.

Samples
- Bulk keeper residue
- Representative sample for analysis
  A# ____, CTC1-3-day/month/time, Batch #

Submit For: U, As, Ni, Co, Fe on solids

SAMPLING INSTRUCTIONS

Sampling Station #3

Name - Leach Discharge

Procedure
- For each sample (3), log an A# withdescription in Sample Book
- Label a 16oz plastic bottle with the sample filtrate A# CTC1-3-1-day/month/time (0-2400h)
- Each batch, take a 500 cc dip sample into the bottle while autoclave is still stirring - measure pH & Redox and record. Get total volume and weight of slurry and record. Add 50 cc of .1% Percol 351 Solution, stir 1 min., filter the sample on an 18.5 cm funnel with #541 paper into a 2L buchner flask - do not allow cake to crack (to ensure properwashing).
- Take a 10 cc pipet aliquot of the "strong filtrate" for free acid titration, before wash solution is added to flask
- Wash cake into same flask with two displacements of 470 cc each of 30 g/L H_2SO_4 solution, not allowing cake to crack
- Rinse sample bottle, shake to drain, measure and note total volume on bottle, return the filtrate to the bottle and put a ~200 cc sample into an identically labelled 8 oz plastic bottle, put remainder into filtrate reject drum
- Wash cake once more into a separate flask, with 470 cc of 10 g/L H_2SO_4 solution. Put portion of filtrate in a 4 oz plastic bottle labelled with the A#, CTC1-3-2-day/mo/time and total wash filtrate volume. Put remainder into filtrate reject drum.
- Label a triple sheet of onion skin paper with the residue A#, CTC 1-3-3-day/mo/time (0-2400h), Place residue on paper and dry cake in oven at 100°C for 4 hours or until dry
- get dry cake weight and record, cut a representative sample of the cake and grind to -100 mesh for analysis
- Bag with label
- CTC1-2-3-day/month/time (0-2400h), Batch # and A#. Save remainder of cake in a separate identically labelled bag.

Samples 1.	Bulk neat + wash filtrate with volume CTC1-3-1
Submit For:	No analyses except analyse immediately for Free Acid, Measure pH and Redox
Samples 2. Do Not Submit	Bulk Wash filtrate - CTC1-3-2, with volume
Samples 3.	Bulk keeper residue, representative sample of residue for analysis Each labelled CTC1-3-3, with total dry weight
Submit For:	U, As, Ni, Cu, Fe

SAMPLING INSTRUCTIONS

Sampling Station #13

Name - #5 Thickener Underflow
Filtrate (13-1) and solids (13-3)

Procedure
- For each sample (2), log an A# with description in Sample Record Book
- Label a 160oz plastic bottle with the sample A#, CTCl-13-1-day/month/time (0-2400h) (End of shift)
- Every 4 hours for 12 hours, take 1.0L sample into the bottle. at the end of the shift, shake sample to mix, and filter on a 12.5 cm funnel with #541 paper, keeping filtrate undiluted. Refilter filtrate on a .45μ paper.
- Rinse the bottle, shake to drain, and return the bulk of the neat filtrate to the bottle and a 100 cc portion to a 4 oz bottle. Acidify the bulk solution for $D^{226}Ra$ with 50 cc HNO_3/L of solution
- Wash the residue well with two displacements of 250 cc of 10 g/L H_2SO_4 solution, then once with 250 cc of water
- Label a triple sheet of onion skin paper with the residue A#, CTCl-13-3-day/month/time (0-2400h) (End of shift), place residue on paper.
- Dry the cake in oven at 100°C for 4 hours or until dry
- Cut a representative sample of the cake and grind to -100 mesh for analysis. Bag with label as below.
- Bag remainder of dry solids with correct A#, CTCl-13-3-day/month/time

Samples 1. Bulk neat filtrate for $D^{226}Ra$, Sample for U, As, Ni
CTCl-13-1-day/month/time

Samples 2 Bulk keeper solids, representative sample of analysis

Submit for: U, As, Ni, $T^{226}Ra$

CTCl-13-3-day/month/time

SAMPLING INSTRUCTIONS

Sampling Station # 19C (Shift Composite)

Name - Clarified Pregnant Feed to Solvent Extraction

Procedure - For each sample (1) log an A # with description in Sample Record Book

- Label an 8 oz plastic bottle with the sample A #, CTC1-19C-day/month/time (0-2400h) (End of Shift)
- Every 4 hours for 12 hours, take a 75 cc sample into the bottle
- At the end of the shift, shake bottle to mix, measure the pH and record.

Samples - Bulk Solution

CTC1-19C-1-day/month/time (0-2400 h)

Sumbit for: U, TSS

Measure pH

SAMPLING INSTRUCTIONS

Sampling Station #19G (4 h Grab)

Name - Clarified Pregnant-Feed
to Solvent Extraction

Procedure - For each sample (1), log an A # with description in Sample Record Book
- Label a 4 oz plastic bottle with the sample A #, CTC1-19G-1-day/month/time (0-2400 h), and "U"
- Fill bottle every 4 hours

Samples - Solution for U (priority)

CTC1-19G-1-day/month/time (0-2400h)

SAMPLING INSTRUCTIONS

Sampling Station #21C (Shift Composite)

Name - Raffinate

Procedure
- For each sample (1), log an A # with description in Sample Record Book
- Label a 160 oz plastic bottle with the sample A #, CTC1-21C-1-day/month/time (0-2400 h) (End of Shift)
- Rinse bottle well with 50 cc of concentrated HnO_3, then rinse well 3 times with 250 cc Distilled Water, shake to drain
- Every 4 hours for 12 hours, take a 500 cc sample into the bottle
- At the end of the shift, shake bottle to mix, measure the pH, Redox and record. Split a 100 cc sample into an identically labelled 4 oz plastic bottle, also labelled U, As,
- Label bulk solution $T^{226}Ra$ and acidify with 50 cc of HNO_3/L of solution

Samples 1 Bulk solution for $T^{226}Ra$

Samples 2 Solution for U, As

CTC1-21C-1-day/month/time (0-2400 h)

Measure pH and Redox

SAMPLING INSTRUCTIONS

Sampling Station # 21G (4 hour Grab)

Name - Raffinate

Procedure	-	For each sample (1), log an A # with description in Sample Record Book
	-	Label a 4 oz plastic bottle with the sample A #, CTCl-21G-1 day/month/time (0-2400 h)
	-	Every 4 hours fill the bottle
Samples		Solution for U
		CTCl-21G-1-day/month/time (0-2400 h)

SAMPLING INSTRUCTIONS

Sampling Station #25

Name - Pregnant Strip Liquor

Procedure - For each sample (1), log an A # with description in Sample Record Book

- Label an 8 oz plastic bottle with the sample A #, CTCI-25-1 day/month/time (0-2400 h) (End of Shift)
- Every 4 hours for 12 hours, take a 75 cc sample into the bottle
- At the end of the shift, measure the pH and record, shake bottle to mix.

Samples Bulk solution

CTCI-25-1-day/month/time (0-2400 h)

Submit For: U

SAMPLING INSTRUCTIONS

Sampling Station #26

Name - Barren Strip Liquor

Procedure - For each sample (1), log an A # with description in Sample Record Book
- Label an 8 oz plastic bottle with the sample A#, CTC1-26-1-day/month/time (0-2400 h) (End of Shift)
- Every 4 hours for 12 hours, take a 75 cc sample into the bottle
- At the end of the shift, shake bottle to mix

Samples Bulk Neat Solution,

CTC1-26-1-day/month/time (0-2400 h)

Submit For: U

SAMPLING INSTRUCTIONS

Sampling Station #40

Name - Drum Filter Filtrate

Procedure
- For each sample (1), log an A # with description in Sample Record Book
- Label a 160 oz plastic jug with the sample A #, CTC1-40-1 day/month/time (0-2400 h) (End of Shift)
- Rinse well with 50 cc of conc. HNO_3, then rinse well 3 times with 250 cc Distilled Water, Shake to drain
- Every 4 hours for 12 hours, take a 1.0L sample into the bottle
- At the end of the shift, shake jug to mix, measure the pH and record. Filter ~1500 cc of the solution on a .45µ filter paper, and split ~1400 cc into a labelled and acid/distilled water rinsed 160 oz plastic bottle and acidify with ~50 cc of HNO_3, label "$D^{226}Ra$".
- Put remainder of -.45µfiltrate into a labelled 4 oz bottle and acidify with 1-2 cc of HCl and label "U, As, Ni ".
- Label original jug "T.S.S."

Samples 1. Bulk filtrate for T.S.S. (as is)

Samples 2. Filtrate for $D^{226}Ra$ (-.45µ filtrate, with HNO_3)

Samples 3. Filtrate for U, As, Ni (-.45µ filtrate, with HCl)

Measure pH

SAMPLING INSTRUCTIONS

Sampling Station # 43

Name - Sand Filter Discharge

Proceduer
- For each sample (1), log an A # with description in Sample Record Book
- Label a 160 oz plastic jug with the sample A #, CTC1-43-1 day/month/time (0-2400 h) (End of Shift)
- Rinse bottle well with ∿50 cc of HNO_3, then rinse well 3 times with 250 cc distilled water, shake to drain
- Every 4 hours for 12 hours, take a 1.2 L sample into the bottle
- At the end of the shift, shake jug to mix, measure the pH and record. Label jug "T^{226}Ra."
- Filter ∿1.5 L of solution on a .45μ filter paper and split ∿1.4L into a labelled and acid/distilled water rinsed 160 oz Jug, also labelled "Diss.^{226}Ra", and acidify with ∿50 cc of HNO_3/L of solution. Acidify T.^{226}Ra sample similarly.
- Put ∿8 oz of -.45μ filtrate before nitric addition into a labelled 8 oz bottle and acidify with ∿3 cc of HCl and label "U, As "

Samples 1. Sample for T.^{226}Ra (with HNO_3)

Samples 2. Sample for Dissolved ^{226}Ra (-.45μ filtrate, with HNO_3)

Samples 3. Sample for metals: U, As (-.45μ filtrate, with HCl)
Measure pH

CTC1-43-1-day/month/time (0-2400 h)

SAMPLING INSTRUCTIONS

Sampling Station #46

Name - Neutralized Tailings
- Filtrate (46-1) and Solids (46-3)

Procedure - For each sample (2), log an A # with description in Sample Record Book

- Label a 160 oz plastic jug with the sample filtrate A #, CTC1-46-1-day/month/time (0-2400 h) (End of Shift)
- Rinse bottle well with ~50 cc of HNO_3, then rinse well 3 times with 250 cc distilled water, shake to drain.
- Every 4 hours for 12 hours, take a 1.5 L slurry sample into the jug. At the end of the shift, shake sample to mix, measure pH and record, and filter on an 18.5 cm funnel with #541 paper, keeping filtrate undiluted.
- Refilter filtrate on a .45µ paper. Rinse the jug, shake to drain, return the bulk of the neat filtrate to the jug, put ~100 cc of filtrate in an identically labelled bottle
- Acidify bulk of filtrate with 50cc of HNO_3/L of solution shake to mix. Label jug "$D^{226}Ra$".
- Acidify the 100 cc sample with ~ 5 cc of HCl, label identically, also U, As, Ni.
- Residue - label a triple sheet of onion skin paper with the residue A #, CTC1-46-3-day/month/time (0-2400 h), place residue on paper.
- Dry cake in oven at 100°C for 4 hours or until dry, cut a representative sample and grind to -100 mesh for analysis, and put it into a properly labelled bag with A#, CTC1-46-3-day/month/time. Put remainder of sample in a similarly labelled bag.

Samples - Filtrate:

1. Solution for U, As, Ni, (-.45µ filtrate, w. HCl)
2. Solution for $D^{226}Ra$ (-.45µ filtrate, w. HNO_3)
   Measure pH

Residue:

1. Bulk dry keeper residue
2. Representative sample for U, As, Ni, and $T^{226}Ra$ analysis

SAMPLING INSTRUCTIONS

Sampling Station #47

Name - Tailings Run-off

Procedure - For each sample (1), log an A # with description in Sample Record Book

- Label a 160 oz plastic jug with the sample A#, CTCl-47-1 day/month/time (0-2400 h) (End of Shift)
- Rinse bottle well with 50 cc of concentrated HNO_3, then rinse well 3 times with 250 cc Distilled Water, shake to drain
- Every 4 hours for 24 hours, take a .5L sample into the bottle
- At the end of the day, measure the pH and record.
- Filter 100 cc portion on a .45μ paper and put in a labelled 4 oz bottle, also labelled "As, Ni", and acidify with ∿2 cc of HCl
- Label original jug "T.^{226}Ra" and acidify with 5 cc HNO_3/100 cc of sample.

Samples:

1. Solution for T.^{226}Ra (w. HNO_3)
2. Solution for As, Ni (-.45μ filtrate w. HCl)

Each labelled CTCl-47-1-day/month/time (0-2400 h)

Measure pH

SAMPLING INSTRUCTIONS

Sampling Station #48

Name - Tailings Seepage

Procedure - For each sample (1), log an A # with description in Sample Record Book

- Label a 160 oz plastic jug with the sample A #, CTC1-48-1 day/month/time (0-2400 h) (End of shift)
- Rinse bottle well with 50 cc of concentrated HNO_3, then rinse well 3 times with 250 cc of Distilled Water, shake to drain
- Every hour for 24 hours, take a .5 L sample into the bottle
- At the end of the day measure the pH and record
- Filter a 100 cc portion on a .45µ paper and put in a labelled 4 oz bottle, also labelled "As, Ni" and acidify with ∿2 cc of HCl
- Label original jug "T.^{226}Ra" and acidify with 5 cc HNO_3/100 cc of sample

Samples 1. Solution for T.^{226}Ra (w. HNO_3)

2. Solution for As, Ni (-.45µ filtrate w. HCl)

Each labelled CTC1-48-1-day/month/time (0-2400 h)

Measure pH

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APPENDIX C

Amount of Yellowcake Produced During the CANMET Campaign

Amount of Yellowcake Produced During the CANMET Campaign

During the CANMET campaign a total of 53.404 kilograms of dry yellow cake was produced. The wet cake contained 50% of moisture. The batch weights of yellow cake produced were as follows:

BATCH NO.s	DRY WEIGHT
# 1	3.572 kg.
2	1.873
3	2.030
4	3.319
5	3.655
6	3.426
7	2.995
8	3.031
9	4.029
10	2.040
11	1.837
12	1.716
13	2.704
14	2.304
15	4.002
16	2.299
17	1.241
18	1.044
19	1.411
20	4.875
	53.404 kg.

The yellow cake produced was shipped to:
Rio Algom Limited
Quirke Mine
Elliot Lake, Ontario.

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APPENDIX D

HYDRO-METEOROLOGICAL DATA SUPPLIED BY THE SASKATCHEWAN RESEARCH COUNCIL PERTAINING TO NORTHERN SASKATCHEWAN

SASKATCHEWAN RESEARCH COUNCIL

30 CAMPUS DRIVE · SASKATOON · SASKATCHEWAN · CANADA · S7N 0X1 · Tel. 306/664-5400 · TELEX 074-2484

Science Serving Saskatchewan

September 7, 1982

Dr. V.I. Lakshmanan, Head
Hydrometeorological Group
Department of Metallurgy
Ontario Research Foundation
Sheridan Park, Ontario
L5K 1B3

Dear Lucky:

Further to our telephone conversation, you can use the following hydrometeorologic data for your simulation programs, for northern Saskatchewan.

Mean hours of Sunshine during summer	12.5 hours
Mean rainfall	30.5 cm - 40.5 cm
Mean snowfall	127 cm - 140 cm
Mean total evaporation	24.4 cm - 30 cm

Snowmelt runoff, estimated from three watersheds in the Cluff Lake area are as follows:

1:5 yrs	1,416,	281,	380	($10^3 m^3/km^2$)
1:25 yrs	2,857,	1,777,	1,470	($10^3 m^3/km^2$)
1:100 yrs	13,500,	5,800,	5,357	($10^3 m^3/km^2$)

I have also included two tables which should give you a rough estimate of watershed yields.

If you have any questions please contact me.

With best wishes,

Sincerely,

G. Lakshman
Principal Research Scientist
Engineering Division

GL/bes

Enclosures

Measured Water Yield
1978 - 1979

	Average Flow (m^3/day)				Annual Water Yield
	Summer July 11-Oct. 31/78	Spring Runoff[1] Apr. 28-July 1/79	Year July 11/78-July 1/79	Winter[5]	x 10^6 m^3
A1 Mill Creek	5011	432[2]	2137	636	0.78
A2 Bridle Creek	35770	44064[3]	19950	4486	7.3
A3 Snake/Island Creek	46900	51840[4]	31150	14161	11.4
Intermediate inflow to A3 or storage (A3 - (A1 + A2))	6119	7344	9063	9039	3.3

[1] spring runoff started late

[2] estimate from 5 readings

[3] 45 days

[4] 61 days

[5] estimated from 4 readings

Theoretical Mean Flow From Mill Creek at Al

Month	Rainfall (mm)	No. of days with rain	Mean Storm amount (mm/hr)		Flow by Rational Method			
			by probability	by means	m^3/s		$\frac{\text{US gal}}{\text{mm}}$	
			a	b	a	b	a	b
Apr.	4.6	2	10	2.3	0.010	0.002	159	80
May	19.8	6		3.3		0.003		
June	33.5	9	25	3.7	0.024	0.004	380	205
July	52.8	10		5.3		0.005		
Aug.	37.6	10		3.8		0.004		
Sept.	34.8	10	10	3.5	0.010	0.003		
Oct.	11.9	6		2.0		0.002	159	80
Nov.	0.0	--						
						mean flow	233	121

Assumption (a) by the probability of the precipitation being equal to or less than.
(b) by mean monthly amounts over 43 years Fort Smith A and Forth Smith (Burns, 1973).

Maximum Flow - Summer and Spring

Return Period	1:5 yr	1:25 yr	Modified 1:25 yr	1:100 yr
Precipitation				
Rain[a] (24 hr) (mm)	35.5	63.5		76.2
Snow[b] (24 hr) (cm)	38.1	58.0		75.7
Summer Flood[c] (m^3s^{-1})				
A1	--	1.7 - 4.8	0.78	2.1 - 6.0
A2	--	5.1 - 12.4	2.35	7.2 - 17.3
A3	--	14.0 - 25.0	6.44	19.6 - 35.0
Spring Melt Flood[d] (m^3s^{-1})				
A1	0.25	0.46	0.17	0.58
A2	1.1	2.04	0.73	2.54
A3	3.4	6.29	2.30	7.85

Source: a. Pollack and Gaye, 1973

b. derived from 1:14 yr

c. Instantaneous flows not daily as derived using Harris, 1978

d. derived using Lakshman, 1976

A1: Mill Creek inflow to Snake Lake

A2: Bridle Creek inflow to Island Creek

A3: Island Creek inflow to Sandy Lake

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APPENDIX E

Table of Air Temperature Readings within the Tailings Facility
For the Period April 1, 1982 - May 31, 1984

TABLE OF AIR TEMPERATURE (^{o}C) READINGS
FOR THE PERIOD APRIL 1 - JUNE 6, 1982

Minimum temperatures given without brackets
Maximum temperatures given within brackets

		N	W	S	E
April	1		9		26
	2		4(12)*		18(25)
	3		3(11)		22(24)
	4		1(2)		20(24)
	5		0(7)		19(23)
	6		-1(7)		23(24)
	7	2	1(17)	21	25(26)
	8	16(21)	4(12)	13(17)	26(28)
	9	20	10	15	28
	10				
	11	19	10	16	25
	12	18(19)	7(13)	14(16)	20(20)
	13				
	14	19(22)	9(18)	15(19)	21(22)
	15	15(21)	8(18)	14(20)	20(22)
	16	22(25)	13(21)	18(22)	24(24)
	17	27	22	25	28
	18	20(21)	10(12)	17(20)	26(28)
	19	23(25)	18(22)	19(23)	27(28)
	20	22(23)	16(18)	19(20)	26(28)
	21	18(19)	7(12)	15(15)	21(28)
	22	15(18)	7(18)	13(17)	20(20)
	23	16(21)	12(20)	17(21)	20(23)
	24	24(25)	23(24)	22(24)	24(25)
	25				
	26	21(21)	16(19)	20(21)	23(24)
	27	19(21)	12(22)	19(21)	22(22)
	28	19(19)	12(18)	17(17)	19(22)
	29	17(20)	14(21)	16(19)	20(21)
	30	16(20)	15(22)	15(20)	16(21)

		N	W	S	E
May	1				
	2	20	20(21)	18(19)	20(21)
	3	18(20)	15(21)	17(20)	19(22)
	4	19(22)	15(22)	17(21)	20(23)
	5	18(20)	14(21)	17(19)	19(20)
	6	15(19)	13(21)	14(19)	15(20)
	7	18(23)	18(24)	18(22)	18(25)
	8	18	18	18	18
	9	20	20(21)	20(21)	21(22)
	10	15(19)	15(20)	15(18)	15(20)
	11	17(19)	16(17)	15(18)	16(19)
	12	17(19)	16(20)	15(19)	17(20)
	13	17(20)	17(22)	17(21)	18(21)
	14	17(20)	17(19)	16(20)	19(22)
	15				
	16	20(22)	20(24)	19(22)	21(23)
	17				
	18	19(21)	19(21)	19(20)	20(22)
	19	19(23)	19(24)	19(23)	20(24)
	20	20(23)	20(24)	20(24)	21(25)
	21	18(24)	17(23)	17(21)	18(29)
	22				
	23				
	24	17	16	17	18
	25	16(19)	15(20)	15(20)	16(20)
	26				
	27	18(19)	16(20)	17(19)	18(21)
	28	20(25)	16(20)	17(21)	20(28)
	29				
	30				

TABLE OF AIR TEMPERATURE READINGS (^{o}C)

FOR THE PERIOD JULY 1 - 31, 1982

Maximum temperatures given without brackets
Minimum temperatures given within brackets

1982 Date	N	S	E	W
July 1	26	25	25	28
2				
3				
4				
5	29(21)	28(21)	30(21)	29(22)
6	29(24)	28(23)	29(23)	29(24)
7	30(30)	-	31(30)	32(29)
8				
9	32(23)	32(24)	34(22)	32(22)
10	31(29)	29(28)	33(32)	32(32)
11	31(28)	29(27)	32(28)	32(29)
12	27	25	28	26
13	27(24)	26(24)	29(24)	29(25)
14	29(28)	27(27)	31(30)	30(30)
15	29(25)	29(23)	32(24)	31(24)
16	39(29)	31(27)	32(28)	35(28)
17	30	29	30	30
18	33(31)	34(33)	32(31)	31(30)
19	39(27)	36(30)	35(27)	31(27)
20	40(27)	35(26)	35(26)	29(25)
21	33(26)	31(25)	32(25)	28(24)
22	39(27)	34(28)	34(27)	29(25)
23	38(31)	33(29)	32(28)	28(26)
24	39(26)	35(27)	35(26)	30(25)
25	41(25)	38(25)	35(25)	31(25)
26	41(28)	37(27)	37(28)	31(27)
27	28(27)	30(26)	38(27)	27(26)
28	27(25)	27(24)	28(25)	26(24)
29	30(24)	32(25)	31(24)	33(23)
30	28(25)	37(25)	33(25)	29(24)
31	31(25)	32(24)	31(26)	28(24)

TABLE OF AIR TEMPERATURE READINGS ($^{\circ}C$)

FOR THE PERIOD AUGUST 1 - AUGUST 31, 1982

Maximum temperatures given without brackets
Minimum temperatures given within brackets

1982 Date	N	S	E	W
Aug 1	40(28)	30(25)	37(22)	34(27)
2	27(26)	25(25)	28(28)	27(26)
3	30(24)	25(23)	-	28(24)
4	38(25)	29(24)	28(26)	33(25)
5	39(25)	30(24)	36(27)	32(26)
6				
7				
8				
9	38(30)	28(25)	35(29)	-
10	36(25)	25(23)	31(26)	-
11	26(23)	25(21)	27(24)	27(25)
12	25(22)	24(20)	24(23)	25(21)
13	37(22)	26(20)	33(21)	29(22)
14	39(26)	29(25)	36(26)	34(27)
15				
16	42(26)	30(24)	39(28)	35(25)
17	40(26)	29(24)	37(28)	33(25)
18	41(23)	29(22)	39(22)	33(23)
19	39(25)	27(23)	31(23)	30(24)
20	41(35)	30(28)	39(33)	34(29)
21				
22				
23	27(25)	25(22)	27(22)	27(24)
24	39(24)	28(21)	38(23)	33(23)
25	39(25)	33(24)	37(27)	33(25)
26	35(24)	29(22)	33(25)	27(22)
27	30(24)	26(23)	27(25)	27(24)
28				
29				
30	25(22)	24(21)	26(23)	23(21)
31	34(27)	28(26)	33(29)	31(26)

TABLE OF AIR TEMPERATURE READINGS (°C)

FOR THE PERIOD SEPTEMBER 1 - 30, 1982

Maximum temperatures given without brackets
Minimum temperatures given within brackets

1982 Date	N	S	E	W
Sept 1	33(26)	27(25)	30(28)	28(25)
2	27(25)	27(25)	28(25)	27(24)
3	38(24)	27(23)	35(25)	27(22)
4				
5				
6				
7	32(23)	26(24)	34(23)	30(23)
8	36(23)	28(23)	36(23)	29(22)
9	27(25)	27(24)	29(26)	29(23)
10	29(27)	29(26)	29(29)	21(25)
11				
12				
13	30(27)	29(27)	32(28)	31(27)
14	30(29)	30(29)	33(20)	30(28)
15	26(24)	25(25)	28(24)	26(25)
16	26(24)	26(24)	26(25)	24(23)
17	34(22)	26(23)	31(23)	29(22)
18				
19				
20	31(22)	27(23)	31(25)	28(21)
21	32(22)	25(21)	27(24)	25(20)
22	36(22)	27(22)	33(23)	27(21)
23	34(25)	27(25)	31(25)	31(24)
24	31(23)	25(23)	28(25)	24(22)
25				
26	32(24)	25(24)	31(24)	24(24)
27				
28	31(25)	26(24)	29(25)	27(24)
29	33(26)	27(25)	32(27)	28(25)
30	32(24)	29(24)	32(27)	31(24)

TABLE OF AIR TEMPERATURE READINGS ($^{\circ}$C)

FOR THE PERIOD OCTOBER 1 - 31, 1982

Maximum temperatures given without brackets
Minimum temperatures given within brackets

1982 Date	N	S	E	W
Oct 1	29(25)	27(24)	29(27)	28(24)
2				
3				
4	35(22)	26(20)	32(22)	29(20)
5	27(21)	24(20)	26(23)	27(20)
6	35(22)	26(21)	31(24)	29(21)
7	36(23)	26(22)	32(23)	27(22)
8	33(21)	25(20)	29(22)	28(19)
9				
10				
11				
12	32(21)	23(21)	28(22)	23(20)
13	31(20)	23(20)	27(21)	24(18)
14	32(20)	23(20)	28(21)	22(19)
15	28(20)	22(19)	25(21)	22(17)
16				
17				
18	32(18)	22(17)	28(19)	22(15)
19	31(21)	23(20)	26(22)	25(19)
20	33(21)	24(20)	29(23)	25(19)
21	27(16)	21(15)	24(19)	19(13)
22	26(16)	20(16)	25(19)	20(14)
23				
24				
25	26(17)	20(15)	23(20)	21(13)
26	24(16)	20(15)	22(19)	22(14)
27	29(16)	22(15)	26(18)	25(13)
28	26(18)	20(16)	24(19)	20(15)
29	35(19)	25(18)	30(22)	26(16)
30				
31				

TABLE OF AIR TEMPERATURE READINGS (°C)

FOR THE PERIOD NOVEMBER 1 - 30, 1982

Maximum temperatures given without brackets
Minimum temperatures given within brackets

1982 Date	N	S	E	W
Nov 1	28(19)	22(20)	24(22)	22(19)
2	34(19)	24(19)	30(20)	26(17)
3	35(22)	26(21)	31(22)	26(20)
4	21(19)	20(18)	22(22)	19(17)
5	15(15)	14(12)	18(18)	13(10)
6				
7				
8	27(18)	23(16)	27(19)	25(15)
9	24(17)	19(16)	23(21)	19(15)
10	26(15)	20(15)	25(19)	27(13)
11	28(21)	22(19)	27(21)	20(16)
12	28(19)	21(19)	27(22)	20(17)
13				
14				
15	22(15)	19(12)	22(18)	19(10)
16	25(12)	19(11)	28(15)	18(9)
17	25(15)	20(14)	23(20)	21(10)
18	20(16)	19(15)	21(20)	19(12)
19	25(17)	21(17)	25(21)	22(15)
20				
21				
22	31(20)	21(18)	25(23)	22(15)
23	32(21)	20(19)	26(23)	20(17)
24	30(19)	18(16)	25(22)	16(12)
25	27(15)	15(12)	25(19)	12(9)
26	27(17)	15(14)	22(20)	13(11)
27				
28				
29	29(18)	16(14)	24(21)	16(13)
30	32(17)	20(15)	25(21)	20(13)

TABLE OF AIR TEMPERATURE READINGS (°C)

FOR THE PERIOD DECEMBER 1 - 31, 1982

Maximum temperatures given without brackets
Minimum temperatures given within brackets

1982 Date	N	S	E	W
Dec 1	33(20)	21(16)	27(21)	23(14)
2	32(23)	21(19)	25(23)	20(18)
3	34(22)	23(19)	24(22)	24(17)
4				
5				
6	30(19)	19(18)	25(20)	16(15)
7	22(18)	17(15)	21(20)	15(11)
8	29(17)	18(14)	23(15)	14(10)
9	22(15)	12(10)	19(16)	10(6)
10	28(13)	13(10)	24(17)	10(7)
11				
12				
13	23(10)	11(5)	19(12)	14(1)
14	29(18)	16(12)	25(20)	12(9)
15	28(19)	19(16)	25(20)	15(14)
16	26(22)	19(18)	25(22)	18(16)
17	25(20)	15(11)	22(22)	14(12)
18				
19				
20	21(19)	17(15)	22(20)	18(14)
21	25(19)	16(15)	25(20)	16(15)
22	31(20)	18(15)	28(23)	18(15)
23	30(22)	20(18)	25(20)	23(19)
24	N.A.*	N.A.	N.A.	N.A.
25	N.A.	N.A.	N.A.	N.A.
26	N.A.	N.A.	N.A.	N.A.
27	N.A.	N.A.	N.A.	N.A.
28	N.A.	N.A.	N.A.	N.A.
29	N.A.	N.A.	N.A.	N.A.
30	N.A.	N.A.	N.A.	N.A.
31	N.A.	N.A.	N.A.	N.A.

*Not Available

TABLE OF AIR TEMPERATURE READINGS (°C)

FOR THE PERIOD JANUARY 1 - 31, 1983

Maximum temperatures given without brackets
Minimum temperatures given within brackets

1983 Date	N	S	E	W
Jan 1				
2				
3				
4	28(13)	17(10)	25(16)	15(7)
5	30(17)	19(13)	27(20)	15(12)
6	24(19)	17(14)	24(20)	17(13)
7	28(21)	15(14)	26(24)	15(13)
8				
9				
10	23(20)	19(17)	25(22)	19(18)
11	23(19)	16(15)	25(21)	15(15)
12	21(20)	17(15)	24(21)	19(15)
13	22(19)	14(12)	24(22)	15(12)
14	24(18)	18(15)	25(21)	20(15)
15				
16				
17	19(17)	13(9)	21(19)	16(7)
18	17(16)	12(8)	20(17)	12(6)
19	20(10)	11(4)	22(14)	14(2)
20	21(13)	12(5)	23(15)	12(4)
21	24(19)	17(10)	26(23)	22(8)
22				
23				
24	24(19)	17(15)	26(22)	17(16)
25	27(20)	18(15)	30(22)	16(14)
26	24(19)	15(12)	23(20)	16(11)
27	18(18)	14(10)	22(21)	15(8)
28				
29	22(20)	15(11)	24(22)	18(10)
30				
31	26(22)	17(15)	29(23)	15(15)

TABLE OF AIR TEMPERATURE READINGS (°C)
FOR THE PERIOD FEBRUARY 1 - 28, 1983

Maximum temperatures given without brackets
Minimum temperatures given within brackets

1983 Date	N	S	E	W
February 1	25(24)	28(17)	27(26)	19(17)
2	25(24)	19(18)	27(26)	20(19)
3	25(19)	19(17)	27(20)	18(15)
4	23(21)	16(13)	26(23)	18(11)
5				
6				
7	25(-)	18(17)	27(25)	22(17)
8	26(19)	17(14)	26(22)	16(15)
9	26(18)	16(13)	28(20)	17(14)
10	22(17)	11(7)	25(21)	10(5)
11	20(19)	12(10)	22(19)	9(7)
12				
13				
14	28(17)	20(12)	29(20)	20(12)
15	26(23)	18(16)	28(22)	17(15)
16	23(21)	18(16)	25(22)	18(25)
17	27(19)	20(16)	26(22)	19(16)
18	29(20)	20(15)	30(21)	23(15)
19				
20				
21	26(-)	19(-)	27(-)	20(-)
22	25(19)	19(16)	26(22)	17(17)
23	27(26)	22(20)	27(25)	23(22)
24	26(26)	20(19)	27(23)	17(16)
25	24(18)	17(15)	25(19)	19(15)
26				
27				
28	25(17)	19(15)	25(20)	21(15)

TABLE OF AIR TEMPERATURE READINGS (^{o}C)
FOR PERIOD MARCH 1 - 31, 1983

Maximum temperatures given without brackets

Minimum temperatures given within brackets

1983 Date	N	S	E	W
March 1	28(19)	22(15)	29(21)	23(16)
2	28(21)	22(15)	28(23)	27(15)
3	22(20)	20(14)	24(20)	21(14)
4	21(16)	18(13)	23(19)	19(13)
5				
6				
7	23(21)	20(18)	25(23)	21(18)
8	26(22)	21(19)	24(23)	24(22)
9	25(25)	19(19)	26(24)	19(18)
10	25(20)	19(17)	25(22)	23(17)
11	23(23)	17(15)	25(21)	16(14)
12				
13				
14	29(19)	20(17)	28(21)	25(18)
15	25(22)	18(16)	25(21)	20(16)
16	30(25)	22(18)	28(24)	29(21)
17	29(21)	21(16)	27(23)	26(19)
18	28(25)	20(20)	27(21)	23(23)
19				
20				
21	25(15)	16(14)	25(15)	19(15)
22	25(23)	17(14)	26(22)	19(13)
23	25(19)	18(14)	25(23)	22(15)
24	25(22)	18(15)	24(22)	23(15)
25	26(18)	19(14)	27(20)	23(16)
26				
27				
28	25(23)	19(17)	25(23)	21(17)
29	24(23)	17(16)	23(20)	22(17)
30	24(23)	15(14)	26(23)	16(14)
31	27(20)	18(15)	22(21)	22(17)

Table of Air Temperature Readings (^{o}C) for the Period April 1-30, 1983

1983 Date		N	S	E	W
April	1				
	2				
	3				
	4	24(20)	18(16)	25(22)	19(16)
	5	26(25)	19(18)	27(25)	21(18)
	6	26(23)	20(18)	27(25)	25(21)
	7	26(24)	21(19)	27(23)	25(20)
	8	26(24)	20(18)	26(23)	23(20)
	9				
	10				
	11	28(21)	22(18)	28(22)	29(21)
	12	28(20)	22(19)	27(20)	28(20)
	13	23(21)	19(18)	24(21)	24(21)
	14	26(23)	20(18)	27(24)	25(24)
	15	22(20)	16(15)	22(18)	20(19)
	16				
	17				
	18	23(18)	17(16)	23(18)	20(18)
	19	22(17)	17(15)	21(17)	21(17)
	20	25(15)	19(16)	23(15)	23(15)
	21	23(15)	18(14)	23(15)	24(14)
	22	25(20)	20(16)	24(21)	25(21)
	23				
	24				
	25	27(20)	22(20)	27(20)	30(22)
	26	25(21)	22(17)	25(23)	28(21)
	27	31(25)	26(21)	30(21)	32(27)
	28	32(21)	25(20)	30(21)	32(22)
	29	25(16)	20(18)	26(15)	28(17)

Table of Air Temperature Readings (^oC) for the Period May 1-31, 1983

1983 Date	N	S	E	W
May 1				
2	26(20)	21(17)	26(21)	24(22)
3	21(17)	18(16)	19(17)	21(18)
4	25(17)	20(15)	26(15)	26(16)
5	25(18)	19(16)	23(16)	25(18)
6	26(18)	21(15)	25(17)	27(18)
7				
8				
9	27(15)	21(14)	26(16)	27(15)
10	28(18)	24(16)	28(19)	31(17)
11	28(22)	21(19)	26(23)	27(22)
12	26(22)	23(18)	26(23)	27(22)
13	29(20)	24(18)	28(22)	31(22)
14				
15				
16	24(20)	20(18)	24(21)	24(20)
17	24(19)	19(16)	23(21)	22(19)
18	24(19)	21(15)	26(20)	28(19)
19	28(20)	21(18)	28(20)	24(20)
20	27(22)	22(20)	27(22)	25(22)
21				
22				
23				
24	26(20)	23(19)	27(20)	30(20)
25	28(21)	23(20)	28(20)	28(21)
26				
27	26(20)	20(16)	26(22)	25(24)
28				
29				
30	28(21)	23(20)	28(21)	29(21)
31	27(22)	21(20)	27(22)	26(23)

Table of Air Temperature Readings ($^{\circ}C$) for the Period June 1-30, 1983

1983 Date	N	S	E	W
June 1	25(22)	21(19)	24(23)	25(23)
2	27(21)	23(18)	26(21)	27(22)
3	29(19)	24(19)	29(19)	32(20)
4				
5				
6	26(23)	21(21)	25(24)	26(24)
7	27(26)	23(20)	26(25)	28(22)
8	28(21)	23(19)	28(22)	28(22)
9	27(23)	23(19)	26(22)	28(21)
10	30(22)	25(21)	30(24)	31(26)
11				
12				
13	36(25)	29(25)	35(24)	37(25)
14	36(31)	30(26)	36(30)	38(31)
15	34(28)	30(25)	32(38)	34(30)
16	35(31)	29(25)	32(30)	34(30)
17	34(27)	30(25)	32(27)	34(29)
18				
19				
20	32(28)	29(25)	31(27)	33(29)
21	35(31)	30(26)	32(30)	35(31)
22	33(28)	30(26)	32(28)	35(29)
23	38(31)	32(26)	36(32)	33(29)
24	35(31)	29(26)	33(28)	35(30)
25				
26				
27	34(28)	30(27)	31(28)	32(30)
28	31(28)	26(24)	30(24)	-(-)
29	31(23)	26(22)	30(22)	-(-)
30	32(30)	27(24)	30(29)	33(-)

Table of Air Temperature Readings (^{o}C) for the Period July 1-31, 1983

1983 date	N	S	E	W
July 1				
2				
3				
4	35(29)	30(28)	34(28)	36(30)
5	32(31)	27(25)	31(30)	33(30)
6	29(26)	25(22)	25(25)	28(27)
7	30(21)	25(20)	27(21)	28(22)
8	33(27)	27(23)	29(26)	31(25)
9				
10				
11	34(27)	29(24)	32(27)	33(27)
12	33(37)	27(31)	31(35)	31(36)
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				

TABLE OF AIR TEMPERATURE READINGS (°C)
FOR THE PERIOD OCT. 14-31/83

1983				
DATE	N	W	S	E
Oct. 1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14	26(22)*	24(21)	25(23)	28(25)
15				
16				
17				
18				
19				
20				
21	22(21)	24(17)	23(20)	25(21)
22				
23				
24	20(20)	19(18)	21(20)	24(19)
25	22(19)	20(17)	21(19)	25(19)
26	27(20)	23(16)	25(19)	29(20)
27	28(25)	22(16)	24(19)	29(25)
28	29(22)	25(17)	26(21)	26(24)
29				
30				
31	28(20)	25(17)	25(14)	30(18)

* max (min)

TABLE OF AIR TEMPERATURE READINGS (°C)

FOR THE PERIOD NOV. 1-30/83

1983				
DATE	N	W	S	E
Nov. 1	28(26)	25(7)	25(20)	30(25)
2	28(25)	23(20)	25(23)	27(25)
3	28(22)	23(21)	25(24)	28(25)
4	26(20)	20(17)	21(19)	27(19)
5				
6				
7	25(20)	23(17)	23(20)	24(20)
8	27(26)	23(19)	25(21)	28(25)
9	28(22)	25(19)	28(21)	30(21)
10				
11	28(24	22(22)	25(23)	29(25)
12				
13				
14	27(18)	20(14)	22(17)	28(18)
15	28(25)	20(17)	22(20)	29(23)
17	25(24)	18(15)	21(18)	26(23)
18	27(22)	18(12)	20(16)	27(22)
19				
20				
21	25(2)0	20(15)	22(19)	25(23)
22	26(23)	22(15)	22(18)	26(22)
23	26(24)	20(15)	23(19)	26(25)
24	25(22)	16(14)	21(19)	24(21)
25	22(19)	14(12)	18(16)	23(18)
26				
27				
28	23(17)	15(13)	18(18)	25(20)
29	22(21)	13(13)	18(15)	23(20)
30	19(17)	10(9)	14(14)	23(18)

* max (min)

TABLE OF AIR TEMPERATURE READINGS (°C)

FOR THE PERIOD DEC. 1-31/83

1983 DATE		N	W	S	E
Dec.	1	22(21)	14(12)	19(15)	24(21)
	2	24(21)	14(11)	19(15)	25(21)
	3				
	4				
	5	24(21)	17(15)	20(19)	26(21)
	6	24(23)	16(11)	21(19)	25(21)
	7	22(21)	12(10)	16(15)	24(22)
	8	25(15)	15(8)	18(16)	26(21)
	9	26(21)	16(12)	19(19)	25(22)
	10				
	11				
	12	26(22)	19(16)	21(21)	29(24)
	13	26(24)	18(16)	20(20)	27(22)
	14	26(23)	18(15)	21(19)	26(20)
	15	25(21)	15(13)	19(18)	26(21)
	16	23(20	13(11)	17(16)	25(21)
	17				
	18				
	19	22(15)	15(9)	18(15)	22(20)
	20	23(17)	15(8)	16(13)	25(19)
	21	22(18)	12(8)	15(15)	24(19)
	22	23(19)	14(10)	18(17)	25(19)
	23	18(17)	5(5)	14(10)	21(19)
	24				
	25				
	26				
	27				
	28				
	29				
	30				
	31				

* max (min)

TABLE OF AIR TEMPERATURE READINGS (°C)
FOR THE PERIOD JAN. 1-31/84

1984 DATE	N	W	S	E
Jan. 1				
2	20(18)	12(11)	18(17)	23(22)
3	20(19)	10(9)	16(15)	23(22)
4	22(16)	11(11)	19(15)	21(17)
5	22(20)	13(10)	18(16)	25(20)
6	22(16)	13(11)	16(15)	24(18)
7				
8				
9	19(14)	9(5)	15(8)	24(11)
10	23(22)	13(8)	16(15)	26(21)
11	21(15)	13(5)	15(10)	25(21)
12	19(18)	8(7)	19(14)	23(20)
13	23(15)	15(7)	19(14)	23(20)
14				
15				
16	20(15)	10(5)	17(12)	25(19)
17	19(18)	9(7)	17(12)	24(20)
18	20(15)	10(7)	16(13)	21(19)
19	18(16)	7(4)	15(12)	22(19)
20	17(11)	6(1)	11(10)	21(16)
21				
22				
23	21(14)	12(5)	16(13)	22(20)
24	20(19)	12(10)	18(16)	24(20)
25	21(19)	13(9)	16(15)	23(20)
26	23(20)	13(12)	16(15)	25(19)
27	24(22)	16(14)	19(17)	25(23)
28				
29				
30	23(18)	14(12)	17(17)	26(19)
31	23(22)	16(11)	20(15)	25(21)

* max (min)

TABLE OF AIR TEMPERATURE READINGS (°C)
FOR THE PERIOD FEB. 1-29/84

1984 DATE	N	W	S	E
Feb. 1	20(15)	14(6)	15(11)	22(18)
2	20(15)	16(9)	16(11)	20(19)
3	17(15)	11(10)	13(12)	19(17)
4				
5				
6	17(16)	10(10)	12(12)	18(16)
8	21(19)	10(8)	13(11)	21(18)
9	26(22)	18(12)	14(12)	24(22)
10	24(17)	16(11)	15(12)	22(17)
11				
12				
13	25(18)	18(14)	18(15)	24(19)
14	25(21)	18(17)	18(17)	23(21)
15	27(25)	23(16)	20(17)	25(23)
16	26(21)	22(16)	19(16)	23(21)
17	25(24)	19(16)	18(16)	23(22)
18				
19				
20	25(19)	15(14)	16(15)	23(20)
21	25(18)	16(15)	16(14)	23(18)
22	22(16)	20(11)	17(13)	21(18)
23	22(21)	23(13)	19(14)	22(20)
24	28(24)	24(16)	21(16)	25(22)
25				
26				
27	27(18)	18(10)	17(12)	24(19)
28	24(24)	15(15)	16(15)	21(21)
29	26(19)	18(13)	16(14)	24(19)
30				
31				

* max (min

ORI

TABLE OF AIR TEMPERATURE READINGS (°C)

FOR THE PERIOD MAR. 1-31/84

1984 DATE	N	W	S	E
Mar. 1	24(22)	17(10)	16(12)	23(21)
2	23(22)	13(12)	13(13)	22(20)
3				
4				
5	25(18)	15(13)	16(15)	24(18)
6	24(22)	16(12)	16(14)	23(22)
7	24(20)	17(9)	15(10)	23(17)
8	23(15)	14(8)	15(10)	23(17)
9	24(18)	14(8)	14(10)	22(18)
10				
11				
12	24(20)	14(7)	14(9)	21(20)
13	25(18)	17(13)	17(14)	25(19)
14	26(20)	19(12)	17(13)	25(19)
15	25(22)	16(13)	16(14)	23(20)
16	26(19)	20(15)	19(15)	23(20)
17				
18				
19	25(17)	17(13)	17(14)	24(19)
20	26(23)	18(15)	17(15)	24(21)
21	27(20)	20(17)	19(17)	24(23)
22	24(20)	13(12)	14(13)	19(22)
23	25(23)	18(12)	17(14)	22(21)
24				
25				
26	25(20)	20(16)	17(15)	25(18)
27	26(19)	23(13)	20(14)	25(20)
28	28(24)	23(16)	21(16)	25(21)
29	27(24)	19(15)	19(16)	25(20)
30	26(21)	28(15)	24(16)	29(21)
31				

* max (min)

TABLE OF AIR TEMPERATURE READINGS (°C)

FOR THE PERIOD APR. 1-30/84

1984 DATE	N	W	S	E
Apr. 1	20(0)	21(0)	27(0)	23(0)
2	30(18)	22(15)	27(19)	24(14)
3	30(22)	23(16)	29(20)	26(15)
4	27(25)	21(18)	24(22)	24(18)
5	27(22)	20(19)	24(22)	20(19)
6	26(25)	18(17)	24(20)	18(17)
7				
8	28(-)	20(-)	24(-)	20(-)
9	27(20)	20(17)	23(20)	23(16)
10	29(26)	21(17)	26(23)	24(18)
11	27(26)	20(18)	25(23)	24(17)
12	30(26)	23(18)	26(23)	26(18)
13	29(26)	21(19)	26(21)	21(19)
14	21(-)	17(-)	20(-)	16(-)
15				
16	28(24)	20(19)	26(24)	21(19)
17	28(24)	18(17)	26(21)	19(16)
18	30(28)	22(19)	27(25)	24(20)
19	30(27)	23(19)	28(22)	25(19)
20				
21				
22				
23	27(20)	18(16)	27(20)	18(15)
24	27(23)	20(18)	25(22)	19(17)
25	28(27)	21(20)	25(24)	24(19)
26	30(28)	24(21)	26(24)	27(21)
27	30(28)	24(20)	27(24)	27(20)
28				
29				
30	30(24)	23(20)	27(24)	23(20)

* max (min)

ORI

TABLE OF AIR TEMPERATURE READINGS (°C)

FOR THE PERIOD MAY. 1-31/84

	1984 DATE	N	W	S	E
May	1	28(20)	20(15)	21(20)	18(13)
	2				
	3	19(19)	16(16)	19(19)	14(14)
	4				
	5				
	6				
	7				
	8	29(20)	20(18)	25(20)	19(17)
	9	28(22)	19(17)	25(20)	24(15)
	11	30(22)	23(18)	26(22)	24(18)
	12				
	13				
	14	22(20)	19(16)	22(20)	18(13)
	15	25(22)	20(19)	22(22)	19(18)
	16	30(25)	24(18)	26(22)	23(16)
	17	26(25)	20(19)	24(21)	20(17)
	18	27(26)	21(18)	25(22)	22(17)
	19	29(29)	22(22)	25(25)	22(22)
	20	23(23)	20(20)	22(22)	20(20)
	21				
	22	30(27)	26(26)	29(24)	28(20)
	23	30(30)	24(23)	26(26)	25(23)
	24	30(21)	23(19)	28(20)	24(18)
	25	33(28)	26(23)	30(26)	26(22)
	26				
	27				
	28	27(24)	21(21)	25(22)	20(20)
	29	28(25)	29(19)	24(22)	18(17)
	30	27(20	20(16)	24(20)	18(15)
	31	28(22)	20(18)	23(20)	19(15)

* max (min)

Canada Centre for Mineral
and Energy Technology
Final Report

APPENDIX F

DAILY RAIN, RUNOFF, SEEPAGE, pH, AND EVAPORATION

ORI

Daily Rain, Runoff, Seepage, pH and Evaporation

April, 1982

Date	Rain (L)	Seepage (L)	Seepage pH	Runoff (L)	Runoff pH	Evaporation from Non-Standard Pans (mL) N	S	E	W	Average
Apr. 6	445	200	11.5	50	6.9	550	140	200	460	337
7	445	190	11.5	40	6.8	570	150	300	410	358
8	445	200	11.5	36	7.0	550	150	200	420	330
9	407	120	11.2	-	7.6	650	170	280	450	388
10	-	-	-	-	-	1,000	380	510	820	677
11	204	40	-	14	-					
12	204	24	-	0	7.4	210	80	110	150	138
13	180	0	9.5	0	7.6					
14	204	50	-	0	7.6	940	260	330	750	570
15	177	0	-	0	-	450	150	240	310	288
16	177	0	-	0	-	600	140	260	570	392
17	177	0	-	0	-	610	150	240	550	388
18	186	60	-	0	7.4					
19	177	-	-	-	-	790	300	530	660	570
20	204	-	-	-	7.4	650	130	190	440	352
21	177	76	-	-	7.5	550	120	300	510	370
22	177	4	-	-	7.8	400	220	260	320	300
23	177	8	-	-	-	260	130	130	270	198
24	177	16	-	-	-					
25	-	-	-	-	-					
26	177	12	8.3	-	7.4	680	490	620	780	642
27	177	-	-	-	-	270	150	260	260	235
28	177	14	-	-	-	250	135	190	240	203
29	177	18	11.3	40	7.3	245	145	140	270	200
30	177	24	-	50	-	170	145	140	180	158

Daily Rain, Runoff, Seepage, pH and Evaporation

May, 1982

Date	Rain (L)	Seepage (L)	Seepage pH	Runoff (L)	Runoff pH	Evaporation from Non-Standard Pans (mL) N	S	E	W	Average
May 1	-	-	-	-	-					
2	177	14	11.1	38	7.5					
3	177	168	11.3	172	7.4	490	190	300	460	360
4	177	36	11.4	64	7.4	310	120	100	150	170
5	177	36	11.6	68	7.4	180	120	180	170	163
6	177	34	11.4	60	7.4	250	110	60	170	148
7	177	18	-	40	-	95	55	30	180	90
8	182	6	-	44	-	190	130	220	150	173
9	182	-	-	-	-					
10	177	100	-	12	-	250	120	150	250	193
11	177	90	-	88	-	155	105	100	145	127
12	168	48	11.5	178	8.3	245	80	85	195	151
13	177	140	11.2	140	7.3	60	65	60	-	61
14	59	144	11.5	136	7.2	160	165	200	150	171
15	170	-	-	-	-					
16	170	180	-	230	-					
17	170	-	11.4	-	7.8	330	290	340	370	332
18	170	70	11.3	90	7.5	215	140	155	210	180
19	170	40	11.1	40	7.4	125	100	100	125	137
20	170	42	11.1	34	7.4	150	100	115	150	128
21	170	42	11.2	40	7.5	120	110	110	130	117
22	170	-	-	-	-					
23	170	-	-	-	-					
24	170	94	-	100	-	570	440	390	380	445
25	170	58	11.5	78	7.5	130	120	90	150	122
26	170	38	11.4	44	7.5					
27	170	42	11.5	48	7.6	200	140	120	130	147
28	170	42	11.4	52	7.3	65	50	60	75	63
29	170	-	-	-	-					
30	170	-	-	-	-					
31	170	126	11.5	146	7.6	260	200	220	510	298

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Daily Rain, Runoff, Seepage, pH and Evaporation

June, 1982

Date	Rain (L)	Seepage (L)	Seepage pH	Runoff (L)	Runoff pH	Evaporation from Non-Standard Pans (mL) N	S	E	W	Average
June 1	172	50	11.5	38	7.6	500	140	90	180	227
2	177	12	10.6	74	7.6	590	210	180	250	307
3	177	6	10.5	23	7.4	750	180	160	260	338
4	177	-	9.4	25	7.5	351	145	97	179	193
5	169	17	-	14	-					
6	169	17	-	14	-	1,590	480	430	680	795
7	169	28	11.2	46	7.4	790	100	150	240	320
8	186	20	11.1	32	7.4					
9	182	12	8.5	23	7.5	640	260	250	340	373
10	141	4	10.1	20	7.4	720	330	350	430	458
11	229	-	-	16	7.5	500	200	180	250	283
12	149	-	-	-	-					
13	149	-	-	-	-					
14	149	4	8.4	58	7.4	1,190	650	680	845	841
15	172	24	9.4	28	7.6	150	140	160	170	155
16	177	32	10.5	30	7.5	250	90	90	150	145
17	179	24	9.6	22	7.5	710	160	160	210	310
18	175	9	9.5	15	7.9	920	190	185	240	384
19	136	12	-	16	-	700	190	250	260	350
20	172	-	-	-	-					
21	173	4	9.1	37	7.4	860	320	390	480	512
22	182	8	10.9	14	7.3	750	180	240	270	363
23	182	10	9.8	20	7.3	610	220	230	250	328
24	173	6	9.2	16	7.5	540	190	230	290	313
25	136	2	7.9	13	7.6	790	260	340	390	445
26	172	4	-	17	-	910	260	390	450	503
27	173	0	-	3	-					
28	182	1	7.8	9	7.2	1,820	650	720	900	1,023
29	141	0	7.9	11	7.3	740	220	350	430	435
30	218	0	7.9	0	7.4	262	180	134	262	209

Daily Rain, Runoff, Seepage, pH and Evaporation

July, 1982

Date	Rain	Seepage		Runoff		Evaporation from Non-Standard Pans (mL)				
	(L)	(L)	pH	(L)	pH	N	S	E	W	Average
July 1	159	18	-	25	-	250	220	170	120	190
2	158	19	-	25	-	240	165	213	173	198
3	158	18	-	25	-	240	165	213	173	198
4	158	19	-	25	-	240	165	213	173	198
5	158	18	8.9	26	7.4	240	165	213	173	198
6	175	28	10.7	30	7.3	150	120	150	150	143
7	170	30	-	30	-	180	125	150	140	149
8	170	31	11.0	30	7.4	180	125	150	140	149
9	170	31	9.5	31	7.2	220	210	210	200	210
10	268	38	11.0	34	7.3	225	180	185	190	195
11	173	38	10.7	34	7.5	225	180	185	190	195
12	59	44	8.7	16	7.8	154	104	160	104	131
13	241	60	7.9	26	7.9	193	133	140	134	150
14	141	44	8.0	18	7.7	193	133	140	134	150
15	182	10	9.4	28	7.7	193	133	140	134	150
16	123	40	9.7	36	7.2	905	90	175	200	343
17	123	20	7.9	14	7.6	905	90	175	200	343
18	236	69+	10.1	9+	7.2	455	130	175	140	225
19	145	47	8.9	35	7.6	455	130	175	140	225
20	173	28	8.1	20	7.4	455	130	175	140	225
21	182	23	7.7	22	7.4	455	130	175	140	225
22	181	25	7.7	21	7.6	440	140	200	160	235
23	218	30	7.5	23	7.5	440	140	200	160	235
24	177	30	8.4	24	7.6	440	140	200	160	235
25	136	29	8.2	23	7.8	440	140	200	160	235
26	177	33	9.2	27	8.0	440	140	200	160	235
27	177	33	9.2	27	8.0	440	140	200	160	235
28	177	36	10.2	28	7.5	360	176	210	184	233
29	136	32	9.2	19	7.5	360	176	210	184	233
30	123	29	8.6	13	8.0	360	176	210	184	233
31	172	7	7.5	15	7.7	360	176	210	184	233

Daily Rain, Runoff, Seepage, pH and Evaporation

August, 1982

Date	Rain (L)	Seepage (L)	Seepage pH	Runoff (L)	Runoff pH	Evaporation from Non-Standard Pans (mL) N	S	E	W	Average
Aug. 1	213	20	7.5	15	7.9	360	176	210	184	233
2	132	11	8.8	21	7.8	360	176	210	184	233
3	136	30	8.5	13	7.6	360	176	210	184	233
4	173	36	8.3	18	8.0	376	183	200	190	237
5	166	36	8.7	26	7.8	376	183	200	190	237
6	166	18	7.5	13	8.0	376	183	200	190	237
7	156	19	-	13	-	376	183	200	190	237
8	156	19	-	13	-	376	183	200	190	237
9	156	19	7.9	13	7.6	376	183	200	190	237
10	182	8	8.6	5	7.5	376	183	200	190	237
11	218	30	8.9	23	7.6	376	183	200	190	237
12	123	30	8.6	13	7.9	376	183	200	190	237
13	141	35	8.0	16	7.9	376	183	200	190	237
14	171	-	9.6	10	7.8	392	197	230	208	257
15	171	46	9.2	20	7.9	392	197	230	208	257
16	171	46	9.1	19	7.9	392	197	230	208	257
17	168	29	8.4	14	7.8	392	197	230	208	257
18	136	12	8.5	11	8.1	392	197	230	208	257
19	164	12	8.2	9	8.0	392	197	230	208	257
20	173	18	7.9	11	7.8	392	197	230	208	257
21	162	20	8.5	8	7.9	392	197	230	208	257
22	162	20	8.0	8	7.9	392	197	230	208	257
23	162	20	8.2	9	7.8	392	197	230	208	257
24	162	23	9.7	19	8.1	392	197	230	208	257
25	177	31	9.5	12	8.1	330	201	211	190	233
26	173	22	8.0	9	7.8	330	201	211	190	233
27	168	30	8.3	9	7.7	330	201	211	190	233
28	162	28	7.7	14	7.8	330	201	211	190	233
29	162	29	8.6	14	7.9	330	201	211	190	233
30	162	29	8.3	15	7.8	330	201	211	190	233
31	189	51	8.0	16	7.7	330	201	211	190	233

Daily Rain, Runoff, Seepage, pH and Evaporation

September, 1982

	Rain	Seepage		Runoff		Evaporation from Non-Standard Pans (mL)				
Date	(L)	(L)	pH	(L)	pH	N	S	E	W	Average
Sept. 1	168	25	7.9	8	7.7	330	201	211	190	233
2	132	34	8.8	20	7.8	330	201	211	190	233
3	173	41	8.9	20	7.6	330	201	211	190	233
4	165	25	7.8	7	7.5	330	201	211	190	233
5	164	25	7.5	7	7.4	330	201	211	190	233
6	165	26	7.2	7	7.3	330	201	211	190	233
7	164	26	7.3	7	7.3	330	201	211	190	233
8	173	20	7.3	28	7.2	277	143	181	139	185
9	177	34	8.1	12	7.6	277	143	181	139	185
10	177	38	7.5	11	7.2	277	143	181	139	185
11	161	41	10.3	16	7.9	277	143	181	139	185
12	162	41	7.3	16	7.3	277	143	181	139	185
13	162	41	9.0	17	7.7	277	143	181	139	185
14	177	45	8.4	15	7.8	277	143	181	139	185
15	182	44	7.8	15	7.4	277	143	181	139	185
16	173	45	7.9	18	7.5	277	143	181	139	185
17	154	47	8.4	13	7.5	277	143	181	139	185
18	172	36	10.0	19	7.5	277	143	181	139	185
19	172	36	7.9	20	7.4	277	143	181	139	185
20	173	37	8.7	20	7.7	277	143	181	139	185
21	173	41	8.2	13	7.6	277	143	181	139	185
22	136	47	8.8	22	7.7	277	143	181	139	185
23	173	39	8.7	18	7.9	277	143	181	139	185
24	168	33	9.3	16	7.9	277	143	181	139	185
25	234	24	8.7	30	7.8	277	143	181	139	185
26	234	25	7.9	30	7.7	277	143	181	139	185
27	81	26	9.3	13	7.1	277	143	181	139	185
28	82	26	9.1	14	7.9	277	143	181	139	185
29	168	49	8.8	12	7.7	372	115	175	115	194
30	168	39	7.6	18	7.8	372	115	175	115	194

Daily Rain, Runoff, Seepage, pH and Evaporation

October, 1982

Date	Rain	Seepage		Runoff		Evaporation from Non-Standard Pans (mL)				Average
	(L)	(L)	pH	(L)	pH	N	S	E	W	
Oct. 1	168	31	8.7	14	8.0	372	115	175	115	194
2	160	52	9.4	17	7.5	372	115	175	115	194
3	160	50	8.0	18	7.9	372	115	175	115	194
4	160	50	9.1	18	7.8	372	115	175	115	194
5	173	36	9.2	19	7.7	372	115	175	115	194
6	173	48	8.6	15	7.5	372	115	175	115	194
7	132	49	8.7	20	8.0	372	115	175	115	194
8	163	50	8.1	20	7.3	372	115	175	115	194
9	160	37	-	21	-	273	83	142	89	147
10	160	37	8.9	22	7.5	273	83	142	89	147
11	160	73	9.3	22	7.3	273	83	142	89	147
12	160	74	9.7	22	7.8	273	83	142	89	147
13	173	55	8.8	17	7.6	273	83	142	89	147
14	173	15	8.7	46	9.1	273	83	142	89	147
15	163	43	7.8	14	7.5	273	83	142	89	147
16	162	17	8.4	23	7.8	273	83	142	89	147
17	162	17	7.8	23	7.8	273	83	142	89	147
18	162	18	10.8	23	7.8	273	83	142	89	147
19	173	4+	10.6	54	8.0	273	83	142	89	147
20	173	18	10.8	24	7.5	273	83	142	89	147
21	173	46	11.0	22	7.6	273	83	142	89	147
22	136	55	10.5	22	7.5	273	83	142	89	147
23	166	37	9.1	27	7.2	273	83	142	89	147
24	167	38	11.2	27	7.9	273	83	142	89	147
25	166	68	5.3	28	5.5	273	83	142	89	147
26	168	120	5.4	24	5.7	273	83	142	89	147
27	132	57	6.5	24	7.0	273	83	142	89	147
28	173	55	7.7	22	7.5	273	83	142	89	147
29	177	53	6.0	16	6.0	273	83	142	89	147
30	171	42	5.6	20	5.5	300	76	166	89	158
31	171	42	5.0	21	5.5	300	76	166	89	158

Daily Rain, Runoff, Seepage, pH and Evaporation

November, 1982

Date	Rain (L)	Seepage		Runoff		Evaporation from Non-Standard Pans (mL)				Average
		(L)	pH	(L)	pH	N	S	E	W	
Nov. 1	171	73	5.3	21	5.8	300	76	166	89	158
2	136	16	5.5	52	5.5	300	76	166	89	158
3	168	40	5.2	16	5.6	300	76	166	89	158
4	177	40	5.1	20	5.6	300	76	166	89	158
5	160	44	5.1	15	5.5	300	76	166	89	158
6	160	60	6.0	21	6.0	300	76	166	89	158
7	160	57	5.0	22	5.4	300	76	166	89	158
8	160	57	5.3	22	5.5	300	76	166	89	158
9	163	43	7.4	16	7.5	557	113	180	83	233
10	168	48	8.5	14	7.8	557	113	180	83	233
11	168	45	9.4	22	7.4	557	113	180	83	233
12	163	40	11.1	17	7.4	302	62	137	87	147
13	153	54	8.1	20	7.5	302	62	137	87	147
14	153	55	7.7	20	7.5	303	63	138	88	149
15	153	54	8.1	19	7.5	303	63	138	88	149
16	173	48	8.2	21	7.7	473	108	165	90	209
17	163	48	7.8	16	7.6	473	108	165	90	209
18	173	16	11.0	11	7.3	472	107	165	90	208
19	160	70	7.7	21	7.7	472	107	165	90	209
20	160	52	8.3	23	7.3	250	76	136	86	137
21	160	52	7.6	24	7.5	250	77	137	87	138
22	160	53	8.2	24	7.5	250	77	137	87	138
23	173	46	7.7	17	7.5	533	97	187	120	234
24	168	36	7.5	16	7.4	533	97	187	120	234
25	127	42	7.0	15	7.4	534	97	187	120	234
26	168	41	7.7	17	7.4	320	96	150	106	168
27	165	50	8.0	21	7.6	320	96	150	106	168
28	165	51	8.0	21	7.7	320	96	150	106	168
29	165	51	7.5	21	7.3	320	96	150	106	168
30	127	41	7.7	17	7.5	320	96	150	106	168

Daily Rain, Runoff, Seepage, pH and Evaporation

December, 1982

Date	Rain	Seepage		Runoff		Evaporation from Non-Standard Pans (mL)				
	(L)	(L)	pH	(L)	pH	N	S	E	W	Average
Dec. 1	163	46	7.5	20	7.5	540	96	170	93	225
2	168	42	7.1	16	7.3	540	97	170	93	225
3	163	8	11.3	7	7.0	540	97	170	94	226
4	153	43	11.4	28	7.1	387	95	182	100	191
5	153	43	8.5	28	7.3	387	95	182	100	191
6	153	44	10.1	28	7.3	388	95	183	100	192
7	150	50	8.3	12	7.2	388	95	183	100	192
8	163	37	8.5	18	7.1	463	113	213	96	221
9	163	47	7.3	6	-	463	113	213	97	222
10	127	40	7.2	28	7.0	464	114	214	97	222
11	162	45	7.2	16	6.9	356	124	188	142	203
12	162	45	7.5	16	7.2	356	124	188	142	203
13	162	46	7.4	16	7.4	356	124	188	142	203
14	159	15	7.4	10	7.2	356	124	188	142	203
15	132	24	6.6	6	6.9	356	124	188	142	203
16	163	14	7.2	4	7.0	755	375	500	440	518
17	168	5	7.2	7	7.1	755	375	500	440	518
18	151	13	7.2	0	7.0	253	250	250	243	249
19	151	13	7.1	0	7.2	253	250	250	243	249
20	152	13	-	1	-	253	250	250	243	249
21	213	18	7.5	0	-	253	250	250	243	249
22	123	9	7.4	0	7.4	259	214	286	250	252
23	213	23	7.5	0	7.4	259	214	286	250	252
24	154	0	7.5	12	7.0	259	214	286	250	252
25	154	18	-	13	-	259	214	286	250	252
26	154	18	7.5	13	-	259	214	286	250	252
27	154	18	7.5	13	7.4	259	214	286	250	252
28	154	18	6.9	13	7.5	259	214	286	250	252
29	154	18	-	13	-	259	214	286	250	252
30	154	18	7.3	13	7.6	259	214	286	250	252
31	154	18	-	13	-	259	214	286	250	252

Daily Rain, Runoff, Seepage, pH and Evaporation

January, 1983

Date	Rain	Seepage		Runoff		Evaporation from Non-Standard Pans (mL)				
	(L)	(L)	pH	(L)	pH	N	S	E	W	Average
Jan. 1	154	18	-	13	7.2	260	215	285	250	253
2	154	40	-	25	-	260	215	285	250	253
3	154	40	-	25	-	260	215	285	150	253
4	154	40	7.7	26	7.8	260	215	285	250	253
5	168	28	7.3	10	7.8	533	296	393	316	385
6	213	23	7.6	10	7.8	533	297	393	317	385
7	123	7	7.6	8	7.6	534	297	394	317	386
8	154	19	7.6	12	7.5	263	240	300	286	272
9	154	20	7.9	12	-	263	240	300	287	273
10	154	20	-	12	7.6	264	240	300	287	273
11	168	15	7.5	14	7.8	250	285	293	278	277
12	94	27	7.6	11	7.6	250	285	293	278	277
13	76	2	7.7	6	7.5	250	285	293	278	277
14	91	13	8.0	17	7.7	250	285	293	278	277
15	165	22	9.1	9	7.5	224	258	270	280	258
16	165	22	7.9	9	7.4	225	258	270	280	258
17	165	23	7.5	10	7.4	224	258	270	280	258
18	168	17	7.1	8	7.6	224	258	270	280	258
19	132	27	7.6	14	7.6	224	258	270	280	258
20	154	24	7.7	8	7.7	243	267	287	270	267
21	163	9	8.5	15	7.6	243	267	287	270	267
22	153	23	8.0	9	7.3	243	267	287	270	267
23	153	22	7.4	1	7.4	243	267	287	270	267
24	153	22	-	1	-	243	267	287	270	267
25	159	17	8.4	40	7.7	243	267	287	270	267
26	159	7	7.1	4	-	300	264	306	305	294
27	168	9	-	7	-	300	264	306	305	294
28	82	10	-	8	-	300	264	306	305	294
29	82	10	9.3	8	-	300	264	306	305	294
30	234	17	7.8	22	7.7	300	264	306	305	294
31	234	18	9.0	22	7.8	300	264	306	305	294

Daily Rain, Runoff, Seepage, pH and Evaporation

February, 1983

Date	Rain	Seepage		Runoff		Evaporation from Non-Standard Pans (mL)				
	(L)	(L)	pH	(L)	pH	N	S	E	W	Average
Feb. 1	163	6	8.5	9	7.8	300	265	305	305	294
2	168	6	-	10	-	300	265	305	305	294
3	132	4	6.7	0	7.1	419	309	410	407	386
4	168	8	-	4	-	419	309	410	407	386
5	165	0	-	8	-	419	309	410	407	386
6	165	0	-	8	-	419	309	410	407	386
7	165	0	-	8	7.1	419	309	410	407	386
8	127	12	6.3	4	-	419	309	410	407	386
9	168	7	7.6	0	7.2	419	309	410	407	386
10	163	4	-	2	-	390	280	370	385	356
11	132	3	7.4	4	7.0	390	280	370	385	356
12	165	10	7.0	14	7.4	240	293	285	295	278
13	165	10	7.3	14	6.7	240	293	285	295	278
14	165	11	7.5	14	6.5	240	293	285	295	278
15	163	15	-	18	-	240	293	285	295	278
16	173	8	7.3	14	6.9	333	293	247	333	302
17	132	7	7.2	19	-	333	293	247	333	302
18	163	17	-	15	6.6	333	293	247	333	302
19	157	9	-	17	-	334	292	334	340	325
20	157	9	7.4	17	6.5	334	292	334	340	325
21	157	10	7.7	12	7.5	334	292	334	340	325
22	157	16	-	12	-	334	292	334	340	325
23	163	15	7.0	8	6.6	334	292	334	340	325
24	163	10	-	3	-	300	288	306	336	308
25	163	11	7.5	13	6.9	300	288	306	336	308
26	148	6	7.2	10	7.5	300	288	306	336	308
27	148	7	-	10	-	300	288	306	336	308
28	148	7	-	11	-	300	288	306	336	308

Daily Rain, Runoff, Seepage, pH and Evaporation

March, 1983

Date	Rain	Seepage		Runoff		Evaporation from Non-Standard Pans (mL)				
Date	(L)	(L)	pH	(L)	pH	N	S	E	W	Average
Mar. 1	163	2	-	1	-	233	259	257	281	258
2	163	0	-	0	-	233	259	257	281	258
3	209	0	-	0	7.3	233	259	257	281	258
4	86	2	-	42	-	233	259	257	281	258
5	163	0	-	14	7.5	233	259	257	281	258
6	163	0	-	14	7.5	233	259	257	281	258
7	163	0	-	15	7.7	233	259	257	281	258
8	163	0	-	9	-	428	288	333	358	352
9	132	39	7.4	10	7.8	428	288	333	358	352
10	159	19	7.1	10	7.7	428	288	333	358	352
11	159	11	7.5	6	7.7	428	288	333	358	352
12	150	9	7.5	7	7.8	470	328	378	403	395
13	150	10	7.5	7	7.8	470	328	378	403	395
14	150	10	6.7	8	7.5	470	328	378	403	395
15	154	13	6.4	8	7.2	470	328	378	403	395
16	163	7	6.6	5	7.6	373	263	323	313	318
17	168	8	6.5	8	7.5	373	263	323	313	318
18	163	12	-	7	-	373	263	323	313	318
19	154	35	6.9	13	7.5	373	263	323	313	318
20	154	35	-	13	-	373	263	323	313	318
21	154	12	6.7	14	7.3	373	263	323	313	318
22	163	21	6.7	12	7.3	373	263	323	313	318
23	152	11	6.9	12	7.4	373	263	323	313	318
24	152	9	6.4	8	7.5	490	328	433	375	407
25	168	7	7.0	4	-	490	328	433	375	407
26	166	17	-	11	7.5	490	328	433	375	407
27	166	17	-	12	-	490	328	433	375	407
28	166	17	7.1	12	7.6	490	328	433	375	407
29	163	5	6.9	13	7.5	490	328	433	375	407
30	136	4	6.9	3	7.3	490	328	433	375	407
31	163	4	6.5	2	7.3	490	328	433	375	407

Daily Rain, Runoff, Seepage, pH and Evaporation

April, 1983

Date	Rain (L)	Seepage (L)	Seepage pH	Runoff (L)	Runoff pH	Evaporation from Non-Standard Pans (mL) N	S	E	W	Average
Apr. 1	159	13	6.3	10	7.4	400	300	370	364	359
2	159	13		10	-	400	300	370	364	359
3	159	14	6.6	10	7.5	400	300	370	364	359
4	159	28	6.9	10	7.5	400	300	370	364	359
5	168	17	7.0	9	7.8	400	300	370	364	359
6	173	18	7.4	8	7.8	353	264	348	342	327
7	0	6	-	2	7.7	353	264	348	342	327
8	0	0	-	0	-	353	274	348	342	327
9	0	0	-	0	-	353	264	348	342	327
10	0	0	-	0	-	353	264	348	342	327
11	0	0	-	0	-	353	264	348	342	327
12	0	0	-	0	-	353	264	348	342	327
13	322	0	7.3	16	7.5	353	264	348	342	327
14	168	4	-	40	7.4	353	264	348	342	327
15	123	1	7.8	13	7.5	353	264	348	342	327
16	114	0	-	2	7.3	248	207	263	297	254
17	114	0	7.0	2	7.5	248	207	263	297	254
18	132	0	-	2	7.4	248	207	263	297	254
19	136	8	7.8	13	8.0	248	207	263	297	254
20	0	0	7.2	0	7.5	248	207	263	297	254
21	45	0	-	0	-	248	207	263	297	254
22	232	0	7.2	0	-	248	207	263	297	254
23	182	23	7.2	19	7.7	286	236	286	363	293
24	182	23	7.0	19	7.6	286	236	286	363	293
25	182	22	7.4	18	7.7	286	236	286	363	293
26	182	32	6.5	16	7.7	286	236	286	363	293
27	182	33	6.6	22	7.5	286	236	286	363	293
28	150	36	6.9	17	7.5	286	236	286	363	293
29	191	36	6.8	16	7.6	286	236	286	363	293
30	136	45	6.7	24	7.7	272	208	249	284	253
Total	3,750	372		298		9,542	7,448	9,419	10,144	9,138

Daily Rain, Runoff, Seepage, pH and Evaporation

May, 1983

	Rain	Seepage		Runoff		Evaporation from Non-Standard Pans (mL)				
Date	(L)	(L)	pH	(L)	pH	N	S	E	W	Average
May 1	236	45	6.7	24	7.6	272	208	249	284	253
2	191	46	7.4	24	7.8	272	208	249	284	253
3	145	43	7.6	19	7.6	272	208	249	284	253
4	182	24	6.9	28	-	272	208	249	284	253
5	182	41	7.0	19	7.8	272	208	249	284	253
6	182	34	7.3	20	7.9	272	208	249	284	253
7	145	42	8.0	20	7.6	272	208	249	284	253
8	222	42	7.5	20	7.7	272	208	249	284	253
9	145	40	7.1	20	7.7	272	208	249	284	253
10	182	34	7.0	18	7.8	272	208	249	284	253
11	182	29	7.0	20	7.7	272	208	249	284	253
12	182	30	7.1	18	7.8	272	208	249	284	253
13	182	30	7.0	22	7.8	281	216	258	308	266
14	182	15	7.0	20	7.8	281	216	258	308	266
15	182	15	7.3	20	7.9	281	216	258	308	266
16	182	15	7.0	20	7.9	281	216	258	308	266
17	182	30	7.3	15	7.8	281	216	258	308	266
18	182	33	7.1	21	7.9	281	216	258	308	266
19	145	37	7.6	16	7.7	281	216	258	308	266
20	182	41	7.3	24	7.2	281	216	258	308	266
21	182	22	7.1	42	7.1	281	216	258	308	266
22	136	22	7.5	42	7.4	281	216	258	308	266
23	182	22	7.8	42	7.5	281	216	258	308	266
24	182	22	7.5	42	6.9	281	216	258	308	266
25	182	14	8.5	36	7.7	281	216	258	308	266
26	182	22	7.0	34	6.6	288	233	288	333	286
27	182	8	7.1	30	7.9	288	233	288	333	286
28	182	39	7.2	22	7.8	288	233	288	333	286
29	182	39	7.2	23	7.7	288	233	288	333	286
30	182	40	7.6	23	7.9	288	233	288	333	286
31	182	37	7.5	20	7.9	288	233	288	333	286
Total	5551	953		764		8,645	6,702	8,070	9,410	8,207

Daily Rain, Runoff, Seepage, pH and Evaporation

June, 1983

Date	Rain	Seepage		Runoff		Evaporation from Non-Standard Pans (mL)				
	(L)	(L)	pH	(L)	pH	N	S	E	W	Average
June 1	182	34	7.4	20	7.9	352	236	281	333	300.5
2	182	30	7.1	19	7.4	352	236	281	333	300.5
3	145	38	7.0	17	7.4	352	236	281	333	300.5
4	182	20	7.7	22	7.7	352	236	281	333	300.5
5	182	20	7.2	23	7.4	352	236	281	333	300.5
6	145	20	10.6	23	7.8	352	236	281	333	300.5
7	54	12	-	0	7.5	352	236	281	333	300.5
8	145	2	7.0	4	7.5	352	236	281	333	300.5
9	182	12	6.6	15	7.9	352	236	281	333	300.5
10	182	17	7.0	17	7.2	500	292	333	408	383.3
11	218	22	6.5	22	7.2	500	292	333	408	383.3
12	145	22	6.4	22	7.3	500	292	333	408	383.3
13	145	23	6.9	22	7.2	500	292	333	408	383.3
14	182	22	6.8	14	7.5	500	292	333	408	383.3
15	182	15	6.6	10	7.3	500	292	333	408	383.3
16	182	17	6.7	14	7.1	584	318	391	485	444.5
17	182	19	-	2	6.6	584	318	391	485	444.5
18	136	8	-	22	6.6	584	318	391	485	444.5
19	182	8	7.2	11	6.6	584	318	391	485	444.5
20	173	8	6.5	10	6.9	584	318	391	485	444.5
21	182	16	6.3	13	6.8	584	318	391	485	444.5
22	145	16	6.4	0	-	584	318	391	485	444.5
23	145	13	-	18	-	584	318	391	485	444.5
24	182	0	-	0	-	507	267	379	471	406.0
25	145	0	-	6	-	507	267	379	471	406.0
26	318	0	6.5	6	7.0	507	267	379	471	406.0
27	73	16	5.9	6	-	507	267	379	471	406.0
28	145	18	5.6	20	6.3	507	267	379	471	406.0
29	182	13	6.1	20	-	507	267	379	471	406.0
30	182	19	-	36	-	507	267	379	471	406.0
Total	5,007	480		434		14,389	8,289	10,308	12,622	11,402.0

Daily Rain, Runoff, Seepage, pH and Evaporation

July, 1983

	Rain	Seepage		Runoff		Evaporation from Non-Standard Pans (mL)				
Date	(L)	(L)	pH	(L)	pH	N	S	E	W	Average
July 1	136	3	-	14	-	413	228	331	275	311.75
2	182	3	-	14	-	413	228	331	275	311.75
3	182	3	6.2	14	6.4	413	228	331	275	311.75
4	182	3	7.0	14	-	413	228	331	275	311.75
5	182	20	6.0	10	-	413	228	331	275	311.75
6	182	24	5.9	0	-	413	228	331	275	311.75
7	182	9	6.5	44	6.4	413	228	331	275	311.75
8	182	33	6.4	20	6.6	413	228	331	275	311.75
9	100	33	6.0	16	6.3	259	221	350	400	307.5
10	182	33	6.0	16	6.4	259	221	350	400	307.5
11	220	32	6.2	16	7.3	259	221	350	400	307.5
12	2,645	457	6.9	12	7.6	259	221	350	400	307.5
13	2,500	973	7.5	416	7.3	259	221	350	400	307.5
14	2,500	994	8.0	828	7.3	259	221	350	400	307.5
15	2,500	726	8.2	604	7.3	259	221	350	400	307.5
16	0	-	-	-	-	250	221	350	400	307.5
17	0	-	-	-	-	259	221	350	400	307.5
18	0	472	0	68	-	259	221	350	400	307.5
19	0	-	-	-	-	259	221	350	400	307.5
20	0	-	-	-	-	259	221	350	400	307.5
21	0	-	-	-	-	-	-	-	-	-
22	0	-	-	-	-	-	-	-	-	-
23	0	-	-	-	-	-	-	-	-	-
24	0	-	-	-	-	-	-	-	-	-
25	0	-	-	-	-	-	-	-	-	-
26	0	-	-	-	-	-	-	-	-	-
CORES EXTRACTED										
27	0	-	-	-	-	-	-	-	-	-
28	0	-	-	-	-	-	-	-	-	-
29	0	-	-	-	-	-	-	-	-	-
30	0	-	7.8	-	8.2	-	-	-	-	-
31	0	-	-	-	-	-	-	-	-	-

Daily Rain, Runoff, Seepage, pH and Evaporation

October, 1983

Date	Rain	Seepage		Runoff		Evaporation from Non-Standard Pans (mL)				
	(L)	(L)	pH	(L)	pH	N	S	E	W	Average
Oct. 1	0	-	-	-	-	-	-	-	-	-
2	0	-	-	-	-	-	-	-	-	-
3	0	-	-	-	-	-	-	-	-	-
4	0	-	-	-	-	-	-	-	-	-
5	0	-	-	-	-	-	-	-	-	-
6	0	-	-	-	-	-	-	-	-	-
7	0	-	-	-	-	-	-	-	-	-
8	0	-	-	-	-	-	-	-	-	-
9	0	-	-	-	-	-	-	-	-	-
10	0	-	-	-	-	-	-	-	-	-
11	0	-	-	-	-	-	-	-	-	-
12	0	-	-	-	-	-	-	-	-	-
13	0	-	-	-	-	-	-	-	-	-
14	0	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	197	257	161	236	213
16	-	-	-	-	-	197	257	161	236	213
17	-	-	-	-	-	197	257	161	236	213
18	-	-	-	-	-	197	257	161	236	213
19	-	-	-	-	-	197	257	161	236	213
20	-	-	-	-	-	197	257	161	236	213
21	227	-	-	-	7.2	197	257	161	236	213
22	182	61	-	27	7.7	237	250	180	231	225
23	227	61	-	27	7.6	237	250	180	231	225
24	241	20	-	27	7.6	237	250	180	231	225
25	182	54	-	21	7.7	237	250	180	231	225
26	182	50	7.2	14	7.7	237	250	180	231	225
27	159	40	7.1	16	7.7	237	250	180	231	225
28	182	18	7.0	6	7.4	237	250	180	231	225
29	136	31	7.0	13	-	389	274	211	274	287
30	159	31	7.0	13	-	389	274	211	274	287
31	250	32	6.9	14	7.5	389	274	211	274	287
Total	1,900	398		178		2,826	2,572	1,893	2,439	2432

Daily Rain, Runoff, Seepage, pH and Evaporation

November, 1983

Date	Rain (L)	Seepage (L)	Seepage pH	Runoff (L)	Runoff pH	Evaporation from Non-Standard Pans (mL) N	S	E	W	Average
Nov. 1	182	38	7.0	24	7.6	389	274	211	274	287
2	95	6	7.2	4	7.7	389	274	211	274	287
3	114	20	-	10	-	389	274	211	274	287
4	136	16	7.2	10	7.8	389	274	211	274	287
5	136	20	7.2	11	7.7	390	250	236	264	285
6	136	20	7.4	11	7.8	390	250	236	264	285
7	136	20	7.3	12	7.5	390	250	236	264	285
8	141	32	7.3	15	7.2	390	250	236	264	285
9	182	36	7.2	17	7.6	390	250	236	264	285
10	(182)	36	7.0	18	7.6	390	250	236	264	285
11	136	36	7.2	18	7.7	390	250	236	264	285
12	145	27	7.2	14	7.6	417	286	236	286	306
13	182	27	7.2	14	7.8	417	286	236	286	306
14	182	28	7.3	14	7.3	417	286	236	286	306
15	182	14	7.2	18	7.5	417	286	236	286	306
16	182	36	7.2	16	7.6	417	286	236	286	306
17	182	36	7.2	14	7.7	417	286	236	286	306
18	182	32	7.4	16	7.7	417	286	236	286	306
19	141	38	7.3	18	7.8	371	286	204	247	277
20	182	38	7.3	19	7.8	371	286	204	247	277
21	182	40	7.3	19	7.7	371	286	204	247	277
22	182	56	7.5	24	7.7	371	286	204	247	277
23	182	37	7.4	17	7.8	371	286	204	247	277
24	145	45	7.3	20	7.9	371	286	204	247	277
25	45	9	-	7	7.9	371	286	204	247	277
26	141	39	7.4	20	8.0	286	229	181	229	231
27	141	40	7.4	20	8.0	286	229	181	229	231
28	218	40	7.0	20	7.0	286	229	181	229	231
29	141	50	6.9	19	7.2	286	229	181	229	231
30	136	48	7.0	21	7.0	286	229	181	229	231
Total	4,649	960		480		11,232	7,995	6,481	7,820	8,382

Daily Rain, Runoff, Seepage, pH and Evaporation

December, 1983

Date	Rain	Seepage		Runoff		Evaporation from Non-Standard Pans (mL)				
	(L)	(L)	pH	(L)	pH	N	S	E	W	Average
Dec. 1	182	47	7.3	20	7.4	286	229	181	229	231
2	182	46	7.1	21	7.2	286	229	181	229	231
3	141	48	7.1	21	7.5	320	281	193	244	260
4	182	48	7.3	21	7.6	320	281	193	244	26
5	182	50	6.7	22	7.1	320	281	193	244	260
6	182	52	6.7	20	7.2	320	281	193	244	260
7	91	15	6.6	11	7.1	320	281	193	244	260
8	100	19	7.1	13	7.8	320	281	193	244	260
9	182	1	-	0	-	320	281	193	244	260
10	(182)	0	-	15	7.9	346	267	216	267	274
11	(182)	0	-	16	7.9	346	267	216	267	274
12	145	0	-	16	7.2	346	267	216	267	274
13	182	16	6.5	25	6.4	346	267	216	267	274
14	182	47	6.8	20	6.8	346	267	216	267	274
15	180	42	6.8	23	6.9	346	267	216	267	274
16	182	36	6.8	19	6.9	346	267	216	267	274
17	(182)	47	6.6	24	7.1	280	240	169	226	229
18	(182)	48	7.0	24	7.4	280	240	169	226	229
19	218	48	6.6	24	6.7	280	240	169	226	229
20	141	49	6.6	21	6.6	280	240	160	226	229
21	182	44	6.4	23	7.0	280	240	169	226	229
22	182	48	6.6	22	6.7	280	240	169	226	229
23	145	41	7.1	18	7.5	280	240	169	226	229
24	182	49	6.7	22	6.8	239	232	171	214	214
25	182	49	6.7	23	6.6	239	232	171	214	214
26	182	49	7.1	23	7.2	239	232	171	214	214
27	182	50	6.7	23	7.3	239	232	171	214	214
28	141	56	6.5	23	7.1	239	232	171	214	214
29	182	56	6.9	24	7.2	239	232	171	214	214
30	182	56	6.5	24	6.9	239	232	171	214	214
31	182	56	7.4	24	7.1	239	232	171	214	214
Total	5,306	1,213		625		9,106	7,830	5,776	7,329	7,510

Daily Rain, Runoff, Seepage, pH and Evaporation

January, 1984

Date	Rain	Seepage		Runoff		Evaporation from Non-Standard Pans (mL)				
	(L)	(L)	pH	(L)	pH	N	S	E	W	Average
Jan. 1	145	57	7.4	24	7.7	239	232	171	214	214
2	218	57	7.0	25	7.1	239	232	171	214	214
3	182	52	7.1	27	7.3	239	232	171	214	214
4	109	22	6.6	12	7.0	239	232	171	214	214
5	109	19	6.5	10	7.0	239	232	171	214	214
6	182	39	7.0	22	7.0	239	232	171	214	214
7	182	31	6.7	21	7.1	313	269	219	257	265
8	182	31	6.6	21	7.0	313	269	219	257	265
9	186	32	6.6	22	7.2	313	269	219	257	265
10	182	48	6.2	23	7.1	313	269	219	257	265
11	182	38	6.5	18	7.1	313	269	219	257	265
12	182	40	6.5	16	7.2	313	269	219	257	265
13	182	48	6.0	21	6.8	313	269	219	257	265
14	182	41	6.9	21	7.3	366	276	203	253	275
15	182	41	6.9	21	7.4	366	276	203	253	275
16	145	42	6.5	21	7.0	366	276	203	253	275
17	182	32	6.7	13	7.3	366	276	203	253	275
18	182	37	6.7	20	7.4	366	276	203	253	275
19	145	39	6.6	19	7.2	366	276	203	253	275
20	182	40	6.6	21	7.2	366	276	203	253	275
21	182	44	6.7	21	7.3	381	234	200	231	262
22	182	45	6.7	22	7.3	381	234	200	231	262
23	182	45	6.7	22	7.3	381	234	200	231	262
24	145	50	6.7	22	7.2	381	234	200	231	262
25	182	48	6.8	24	6.8	381	234	200	231	262
26	182	49	6.5	20	7.2	381	234	200	231	262
27	182	43	6.7	24	7.3	381	234	200	231	262
28	141	30	6.9	24	7.3	336	249	193	234	253
29	182	29	6.9	24	7.1	336	249	193	234	253
30	182	29	6.7	23	7.3	336	249	193	234	253
31	182	52	6.6	14	-	336	249	193	234	253
Total	5,347	1,250		638		10,198	7,841	6,152	7,407	7,900

Daily Rain, Runoff, Seepage, pH and Evaporation

February, 1984

	Rain	Seepage		Runoff		Evaporation from Non-Standard Pans (mL)				
Date	(L)	(L)	pH	(L)	pH	N	S	E	W	Average
Feb. 1	182	32	6.6	19	7.3	336	249	193	234	253
2	182	52	6.8	40	7.4	336	249	193	234	253
3	136	60	6.8	28	7.3	336	249	193	234	253
4	(182)	59	7.2	29	7.7	296	143	166	143	187
5	(182)	60	7.2	29	7.6	296	143	166	143	187
6	218	60	6.7	29	7.3	296	143	166	143	187
7	182	68	6.5	28	7.1	296	143	166	143	187
8	100	52	6.5	26	7.3	296	143	166	143	187
9	182	34	7.0	21	7.6	296	143	166	143	187
10	182	44	6.5	25	7.2	296	143	166	143	187
11	136	52	7.0	28	7.3	469	154	231	189	261
12	182	52	7.1	28	7.3	469	154	231	189	261
13	182	53	6.6	40	7.4	469	154	231	189	261
14	182	52	6.7	28	7.2	469	154	231	189	261
15	182	43	6.7	26	7.2	469	154	231	189	261
16	182	44	6.5	24	7.3	469	154	231	189	261
17	145	39	6.7	28	7.3	469	154	231	189	261
18	0	0	-	0	-	471	176	219	196	266
19	0	0	-	0	-	471	176	219	196	266
20	182	4	-	8	6.9	471	176	219	196	266
21	136	4	6.9	24	7.3	471	176	219	196	266
22	182	15	6.3	17	7.0	471	176	219	196	266
23	136	36	6.3	25	6.9	471	176	219	196	266
24	182	41	6.3	21	7.0	471	176	219	196	266
25	(182)	33	8.5	3	7.2	471	176	219	196	266
26	(182)	33	7.0	3	7.0	471	176	219	196	266
27	204	34	7.3	3	8.0	471	176	219	196	266
28	182	39	-	0	-	471	176	219	196	266
29	145	45	7.2	4	7.9	471	176	219	196	266
	4632	1140		584		12051	4938	5986	537	7088

Daily Rain, Runoff, Seepage, p^H and Evaporation

March, 1984

	Rain	Seepage		Runoff		Evaporation from Non-Standard Pans (mL)				
Date	(L)	(L)	p^H	(L)	p^H	N	S	E	W	Average
Mar. 1	195	42	7.1	26	7.8	480	171	246	200	274
2	182	40	7.1	27	8.0	480	171	246	200	274
3	145	46	7.2	28	7.9	410	179	210	176	244
4	182	46	7.2	28	7.8	410	179	210	176	244
5	182	56	7.1	29	7.7	410	179	210	176	244
6	182	45	6.6	28	7.3	410	179	210	176	244
7	182	39	7.0	27	8.3	410	179	210	176	244
8	182	32	6.9	25	7.5	410	179	210	176	244
9	145	40	6.8	28	7.5	410	179	210	176	244
10	182	34	6.8	24	7.4	517	195	233	187	283
11	182	-	6.9	28	7.5	517	195	233	187	283
12	182	92	7.0	22	7.5	517	195	233	187	283
13	182	52	67.8	30	7.6	517	195	233	187	283
14	145	44	6.8	26	7.6	517	195	233	187	283
15	182	40	6.8	28	7.5	517	195	233	187	283
16	182	43	6.9	24	7.6	477	171	231	190	267
17	182	-	7.2	36	7.5	477	171	231	190	267
18	136	-	7.2	37	7.5	477	171	231	190	267
19	145	146	7.3	80	7.6	477	171	231	190	267
20	218	50	6.9	25	7.4	477	171	231	190	267
21	182	42	6.8	25	7.5	477	171	231	190	267
22	182	36	7.0	20	7.5	477	171	231	190	267
23	136	36	7.0	20	7.5	477	171	231	190	267
24	182	-	7.2	-	7.8	575	191	275	21(	313
25	182	85	7.2	-	7.4	575	191	275	21(	313
26	182	39	6.8	73	7.4	575	191	275	21(	313
27	182	41	6.8	25	7.6	575	191	275	21(	313
28	182	40	7.0	22	7.6	575	191	275	21(	313
29	145	33	7.0	20	7.6	575	191	275	21(	313
30	159	32	7.3	20	8.0	575	191	275	21(	313
31	159	56	7.3	52	7.7	575	191	275	21(	313
	5368	1327		883		15348	5661	7408	5962	8594

Daily Rain, Runoff, Seepage, pH and Evaporation

April, 1984

	Rain	Seepage		Runoff		Evaporation from Non-Standard Pans (mL)				
Date	(L)	(L)	pH	(L)	pH	N	S	E	W	Average
Apr. 1	182	0	7.4	0	7.7	457	208	305	192	290.5
2	204	36	7.3	20	7.8	457	208	305	192	290.5
3	145	42	7.5	27	7.8	457	208	305	192	290.5
4	182	36	7.6	21	8.0	457	208	305	192	290.5
5	182	35	7.2	20	-	457	208	305	192	290.5
6	136	21	7.3	22	7.6	457	208	305	192	290.5
7	0	3	-	0	7.3	614	217	326	253	352.5
8	145	1	7.3	2	7.6	614	217	326	253	352.5
9	182	8	7.2	24	7.6	614	217	326	253	352.5
10	182	28	7.2	20	7.6	614	217	326	253	352.5
11	182	28	7.2	20	7.7	614	217	326	253	352.5
12	136	28	7.4	20	7.6	614	217	326	253	352.5
13	182	28	7.3	20	7.5	614	217	326	253	352.5
14	145	24	7.2	16	7.6	650	236	313	219	354.5
15	145	36	7.0	27	7.6	650	236	313	219	354.5
16	218	44	-	24	-	650	236	313	219	354.5
17	145	34	-	24	-	650	236	313	219	354.5
18	45	2	-	8	-	650	236	313	219	354.5
19	182	0	-	12	-	650	236	313	219	354.5
20	145	12	-	18	-	650	236	313	219	354.5
21	204	23	-	3	-	486	200	268	211	291.0
22	182	45	-	37	-	486	200	268	211	291.0
23	182	46	-	22	-	486	200	268	211	291.0
24	182	46	6.9	24	7.2	486	200	268	211	291.0
25	182	39	7.0	20	7.5	486	200	268	211	291.0
26	182	37	7.0	20	7.4	486	200	268	211	291.0
27	182	36	7.1	20	7.4	486	200	268	211	291.0
28	170	32	-	20	-	486	200	268	211	291.0
29	170	32	-	20	-	486	200	268	211	291.0
30	182	57	7.1	30	7.5	486	200	268	211	291.0
Total	4883	839		581		16,450	6,419	8,983	6,566	964.0

Daily Rain, Runoff, Seepage, pH and Evaporation

May, 1984

	Rain	Seepage		Runoff		Evaporation from Non-Standard Pans (mL)				
Date	(L)	(L)	pH	(L)	pH	N	S	E	W	Average
May 1	113	16	-	9	7.5	341	163	218	151	218
2	147	-	-	-	-	341	163	218	151	218
3	147	60	-	36	-	341	163	218	151	218
4	0	-	-	-	-	341	163	218	151	218
5	0	-	-	-	-	341	163	218	151	218
6	0	-	-	-	-	341	163	218	151	218
7	0	-	-	-	-	341	163	218	151	218
8	182	36	6.9	64	7.2	341	163	218	151	218
9	182	52	6.9	48	7.3	341	163	218	151	218
10	182	12	6.9	64	7.2	341	163	218	151	218
11	182	44	6.9	0	7.1	341	163	218	151	218
12	113	40	-	40	-	522	193	268	186	292
13	227	47	6.8	26	7.2	522	193	268	186	292
14	182	45	6.8	26	7.1	522	193	268	186	292
15	182	48	6.8	28	7.2	522	193	268	186	292
16	182	23	6.4	25	6.8	522	193	268	186	292
17	145	21	6.5	19	7.2	522	193	268	186	292
18	182	34	-	20	-	522	193	268	186	292
19	136	2	6.8	0	7.2	497	186	267	193	286
20	136	48	-	20	-	497	186	267	193	286
21	213	67	-	10	-	497	186	267	193	286
22	182	54	6.8	25	7.2	497	186	267	193	286
23	182	44	-	21	-	497	186	267	193	286
24	182	42	-	23	-	497	186	267	193	286
25	136	44	-	21	-	497	186	267	193	286
26	136	33	7.0	0	7.1	567	187	275	180	302
27	182	39	7.0	44	7.3	567	187	275	180	302
28	218	48	6.4	20	7.0	567	187	275	180	302
29	182	36	6.8	21	7.2	567	187	275	180	302
30	182	45	7.0	23	7.4	567	187	275	180	302
31	145	44	6.9	22	7.3	567	187	275	180	302
	4560	1024		651		14286	5568	7793	5394	8256

Canada Centre for Mineral
and Energy Technology
Final Report

APPENDIX G

VARIATION IN THE TAILINGS BED TEMPERATURE BETWEEN JUNE 1, 1982 AND MARCH 1, 1983

VARIATION IN THE TAILINGS BED TEMPERATURE
FOR SPECIFIC PERIODS
(Maximum & Minimum Temperature Shown)

THERMO COUPLE NO.	GRID	DEPTH	JUNE 1 - 6	JUNE 7 - 12	JUNE 13 - 18	JUNE 19 - 24	JUNE 25 - 30
1	C-3	10	18 - 32°C	19 - 36°C	19 - 35°C	22 - 38°C	27 - 37°C
2		20	16 - 22°C	20 - 27°C	18 - 26°C	20 - 26°C	23 - 29°C
3		40	19 - 26°C	19 - 24°C	21 - 23°C	23 - 25°C	22 - 27°C
4	D-7	10	22 - 27°C	24 - 33°C	24 - 33°C	29 - 35°C	32 - 38°C
5		20	23 - 27°C	24 - 31°C	25 - 31°C	30 - 33°C	31 - 38°C
6		40	20 - 25°C	22 - 27°C	24 - 27°C	28 - 29°C	27 - 32°C
7	G-8	10	21 - 30°C	26 - 35°C	23 - 38°C	28 - 37°C	33 - 38°C
8		20	22 - 26°C	26 - 32°C	25 - 32°C	28 - 33°C	31 - 37°C
9	H-5	10	19 - 23°C	22 - 28°C	21 - 27°C	21 - 27°C	25 - 30°C
AMBIENT							
10	EAST		18 - 36°C	21 - 37°C	19 - 38°C	27 - 38°C	33 - 38°C
11	West		13 - 24°C	14 - 34°C	16 - 26°C	18 - 27°C	22 - 26°C
12	STACK OUT		18 - 37°C	24 - 38°C	19 - 38°C	20 - 38°C	30 - 38°C

NB Temperatures shown are the average daily minimum and average daily maximum

VARIATIONS IN THE TAILINGS BED TEMPERATURE

FOR SPECIFIC PERIODS IN JULY 1982

(Minimum & Maximum Temperatures Shown, °C)

Thermocouple No.	Grid	Depth (cm)	July 1 - 7	July 8 - 15	July 16 - 23	July 24 - 31
1	C - 3	10	21 - 34	20 - 33	33 - 36	19 - 37
2	C - 3	20	21 - 23	19 - 25	24 - 27	19 - 28
3	C - 3	40	11 - 20	14 - 27	14 - 21	27 - 33
4	D - 7	10	28 - 30	28 - 31	28 - 35	28 - 34
5	D - 7	20	28 - 30	28 - 30	29 - 32	28 - 34
6	D - 7	40	27 - 29	26 - 28	27 - 29	27 - 32
7	G - 8	10	26 - 32	26 - 34	29 - 60	21 - 42
8	G - 8	20	24 - 29	27 - 30	30 - 34	28 - 33
9	H - 5	10	22 - 25	24 - 27	26 - 33	23 - 28
10	Ambient - East		23 - 37	22 - 39	26 - 42	22 - 43
11	Ambient - West		22 - 30	19 - 29	22 - 31	20 - 32
12	Ambient Stack Out		22 - 36	21 - 36	23 - 50	21 - 54

VARIATIONS IN THE TAILINGS BED TEMPERATURE
FOR SPECIFIC PERIODS IN AUGUST, 1982
(Minimum & Maximum Temperatures Shown ^{o}C)

Thermocouple No.	Grid	Depth (cm)	August 1 - 7	August 8 - 15	August 16 - 23	August 24 - 31
1	C - 3	10	19 - 38	16 - 37	17 - 41	18 - 38
2	C - 3	20	19 - 24	18 - 31	16 - 26	14 - 21
3	C - 3	40	26 - 27	24 - 31	24 - 33	22 - 29
4	D - 7	10	28 - 34	27 - 33	27 - 39	24 - 32
5	D - 7	20	28 - 31	27 - 33	27 - 34	24 - 30
6	D - 7	40	27 - 28	26 - 32	26 - 33	23 - 28
7	G - 8	10	25 - 43	22 - 44	17 - 42	24 - 49
8	G - 8	20	27 - 35	27 - 34	18 - 49	23 - 37
9	H - 5	10	23 - 26	21 - 26	22 - 27	18 - 33
10	Ambient - East		21 - 44	17 - 43	18 - 48	18 - 43
11	Ambient - West		19 - 29	16 - 28	17 - 29	16 - 27
12	Ambient Stack Out		20 - 43	16 - 42	17 - 54	18 - 53

VARIATIONS IN THE TAILINGS BED TEMPERATURE
FOR SPECIFIC PERIODS IN SEPTEMBER 1982
(Minimum & Maximum Temperatures Shown °C)

Thermocouple No.	Grid	Depth (cm)	September 1 - 7	September 8 - 15	September 16 - 23	September 24 - 30
1	C - 3	10	16 - 41	15 - 38	24 - 30	Recorder sent out for Repairs
2	C - 3	20	16 - 23	15 - 19	15 - 20	
3	C - 3	40	26 - 34	8 - 29	9 - 40	
4	D - 7	10	27 - 34	26 - 28	24 - 28	
5	D - 7	20	27 - 30	24 - 27	26 - 28	
6	D - 7	40	24 - 27	23 - 26	16 - 24	
7	G - 8	10	20 - 37	16 - 38	26 - 28	
8	G - 8	20	17 - 33	16 - 39	28 - 32	
9	H - 5	10	19 - 26	19 - 25	19 - 22	
10	Ambient - East		17 - 46	15 - 43	24 - 32	
11	Ambient - West		14 - 24	15 - 25	16 - 23	
12	Ambient Stack Out		16 - 64	16 - 56	23 - 52	

VARIATIONS IN THE TAILINGS BED TEMPERATURE
FOR SPECIFIC PERIODS IN OCTOBER 1982
(Minimum & Maximum Temperatures Shown ^{o}C)

Thermocouple No.	Grid	Depth (cm)	October 1 - 7	October 8 - 15	October 16 - 23	October 24 - 31
1	C - 3	10	19 - 31	16 - 29	15 - 28	13 - 28
2	C - 3	20	21 - 25	19 - 24	17 - 26	16 - 21
3	C - 3	40	17 - 20	-------	-------	-------
4	D - 7	10	27 - 32	26 - 31	24 - 30	22 - 28
5	D - 7	20	28 - 29	26 - 29	24 - 27	24 - 26
6	D - 7	40	27 - 27	25 - 27	24 - 26	23 - 26
7	G - 8	10	20 - 56	18 - 53	18 - 50	14 - 52
8	G - 8	20	21 - 52	19 - 48	16 - 52	15 - 53
9	H - 5	10	23 - 26	22 - 25	19 - 23	16 - 22
10	Ambient - East		20 - 55	18 - 55	16 - 53	16 - 50
11	Ambient - West		20 - 31	17 - 29	16 - 28	13 - 29
12	Ambient Stack Out		20 - 31	17 - 31	16 - 29	14 - 30

VARIATIONS IN THE TAILINGS BED TEMPERATURE
FOR SPECIFIC PERIODS IN NOVEMBER 1982
(Minimum & Maximum Temperatures Shown °C)

Thermocouple No.	Grid	Depth (cm)	November 1 - 7	November 8 - 15	November 16 - 23	November 24 - 30
1	C - 3	10	17 - 31	15 - 26	22 - 22	21 - 23
2	C - 3	20	18 - 24	17 - 19	20 - 21	20 - 21
3	C - 3	40	-------	18 - 19	20 - 21	20 - 21
4	D - 7	10	24 - 31	22 - 28	20 - 26	22 - 26
5	D - 7	20	26 - 29	24 - 26	21 - 26	23 - 26
6	D - 7	40	24 - 27	23 - 24	19 - 24	23 - 26
7	G - 8	10	22 - 57	16 - 57	28 - 49	21 - 56
8	G - 8	20	24 - 57	22 - 58	51 - 51	-------
9	H - 5	10	18 - 24	18 - 24	22 - 24	20 - 24
10	Ambient - East		22 - 52	15 - 55	31 - 48	20 - 41
11	Ambient - West		17 - 29	14 - 27	23 - 28	18 - 27
12	Ambient Stack Out		14 - 31	15 - 32	25 - 34	19 - 34

VARIATIONS IN THE TAILINGS BED TEMPERATURE
FOR SPECIFIC PERIODS IN DECEMBER, 1982
(Minimum & Maximum Temperatures Shown, °C)

Thermocouple No.	Grid	Depth (cm)	December 1 - 7	December 8 - 15	December 16 - 23	December 24 - 31
1	C - 3	10	21 - 23	16 - 21	------	------
2	C - 3	20	21 - 22	16 - 21	------	------
3	C - 3	40	20 - 21	18 - 21	------	------
4	D - 7	10	22 - 28	18 - 26	------	------
5	D - 7	20	24 - 27	21 - 25	------	------
6	D - 7	40	24 - 26	22 - 25	------	------
7	G - 8	10	26 - 54	21 - 28	------	------
8	G - 8	20	-------	23 - 26	------	------
9	H - 5	10	21 - 24	16 - 22	------	------
10	Ambient - East		21 - 43	18 - 34	------	------
11	Ambient - West		17 - 28	6 - 23	------	------
12	Ambient Stack Out		19 - 74	13 - 32	------	------

VARIATIONS IN THE TAILINGS BED TEMPERATURE
FOR SPECIFIC PERIODS IN JANUARY, 1983
(Minimum & Maximum Temperatures Shown, °C)

Thermocouple No.	Grid	Depth (cm)	January 1 - 7	January 8 - 15	January 16 - 23	January 24 - 31
1	C - 3	10	13 - 18	16 - 18	14 - 16	16 - 19
2	C - 3	20	13 - 16	16 - 17	14 - 15	16 - 19
3	C - 3	40	14 - 16	16 - 17	15 - 16	16 - 17
4	D - 7	10	15 - 23	18 - 20	16 - 18	17 - 23
5	D - 7	20	17 - 21	18 - 21	18 - 19	19 - 21
6	D - 7	40	17 - 19	17 - 20	18 - 19	18 - 19
7	G - 8	10	21 - 27	23 - 25	21 - 22	22 - 25
8	G - 8	20	29 - >93	21 - >93	- >93	- >93
9	H - 5	10	12 - 29	14 - 26	10 - 24	13 - 29
10	Ambient East		16 - 34	21 - 29	14 - 29	18 - 34
11	Ambient West		4 - 12	7 - 16	-2 - 12	4 - 14
12	Ambient Stack Out		13 - 60	18 - 31	12 - 33	18 - 36

VARIATIONS IN THE TAILINGS BED TEMPERATURE
FOR SPECIFIC PERIODS IN FEBRUARY, 1983
(Minimum & Maximum Temperatures Shown, °C)

Thermocouple No.	Grid	Depth (cm)	February 1 - 7	February 8 - 15	February 16 - 23	February 24 - 28
1	C - 3	10	19 - 22	17 - 23	19 - 22	18 - 21
2	C - 3	20	18 - 21	17 - 22	18 - 20	17 - 19
3	C - 3	40	17 - 19	18 - 21	18 - 20	17 - 19
4	D - 7	10	23 - 29	20 - 30	22 - 27	20 - 25
5	D - 7	20	23 - 28	22 - 27	23 - 25	22 - 25
6	D - 7	40	21 - 25	22 - 25	22 - 23	22 - 24
7	G - 8	10	26 - 30	24 - 29	27 - 37	38 - 40
8	G - 8	20	33 - >93	29 - >93	-------	-------
9	H - 5	10	19 - 78	16 - 29	16 - 28	14 - 28
10	Ambient East		23 - 31	19 - 33	21 - 32	18 - 32
11	Ambient West		7 - 16	1 - 16	9 - 19	11 - 18
12	Ambient Stack Out		22 - 32	18 - 36	19 - 36	17 - 35

VARIATIONS IN THE TAILINGS BED TEMPERATURE
FOR SPECIFIC PERIODS IN MARCH, 1983
(Minimum & Maximum Temperatures Shown ^{o}C)

Thermocouple No.	Grid	Depth (cm)	March 1 - 7	March 8 - 15	March 16 - 23	March 24 - 31
1	C - 3	10	18 - 21	19 - 22	16 - 22	19 - 22
2	C - 3	20	18 - 18	18 - 21	17 - 21	14 - 18
3	C - 3	40	18 - 19	18 - 20	18 - 21	18 - 20
4	D - 7	10	21 - 24	22 - 27	18 - 28	12 - --
5	D - 7	20	22 - 23	22 - 26	21 - 27	24 - 28
6	D - 7	40	22 - 23	21 - 24	22 - 25	23 - 26
7	G - 8	10	39 - 45	------	------	------
8	G - 8	20	------	------	------	------
9	H - 5	10	16 - 29	16 - 29	10 - 29	14 - 29
10	Ambient East		19 - 33	21 - 36	13 - 33	20 - 33
11	Ambient West		11 - 24	10 - 23	9 - 24	9 - 19
12	Ambient Stack Out		19 - 36	20 - 34	14 - 33	19 - 35

FREEZE - THAW CYCLES - TEMPERATURE DATA

Cylce NO.	1983 Date	Tailings Bed Temperature at 30 cm.
		°C
2 (Thaw)	June 6	- 1.1
	8	7.2
	9	18.3
	10	21.7
	13	23.9
	14	27.8
	16	22.8
	17	25.6
3 (Freezing)	June 20	-17.8
4 (Thaw)	June 24	-1.7
	27	20.6
	28	22.2
	29	21.1
	30	22.8
	July 4	24.4
	5	26.1
	6	23.9
	7	22.2
	8	26.1
5 (Freezing)	July 11	-2.2

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APPENDIX H

U, As, Ni AND Ra_{226} ANALYSIS OF SEEPAGE AND RUNOFF SOLUTIONS

EFFLUENT SOLUTIONS-FLOWS AND ANALYSES

	Seepage					Runoff				
Sample Period	Flow L	U mg/L	As mg/L	Ni mg/L	Ra pCi/L	Flow L	U mg/L	As mg/L	Ni mg/L	Ra pCi/L
6/4/82 - 11/4/82	750	1.11	7.9	0.15	12	140	1.6	14.4	0.21	6
12/4/82 - 18/4/82	134	1.39	4.5	0.09	18	0	1.42	-	-	-
19/4/82 - 26/4/82	116	1.24	23.1	0.15	10	0	1.28	-	-	-
27/4/82 - 3/5/82	238	0.49	4.4	0.09	13	300	2.03	15.0	0.29	3
4/5/82 - 9/5/82	130	0.69	5.3	0.18	8	276	2.03	21.1	0.12	3
10/5/82 - 16/5/82	702	0.74	5.3	0.12	21	784	0.47	32.0	0.22	4
17/5/82 - 28/5/82	468	0.50	4.2	0.12	11	526	1.73	27.0	0.15	6
29/5/82 - 31/5/82	126	0.97	4.3	0.12	20	146	1.34	28.4	0.12	10
1/6/82 - 6/67/82	102	1.93	18.3	0.23	4	188	1.76	35.4	0.20	4
7/6/82 - 13/6/82	64	1.13	12.8	0.03	9	137	1.95	30.6	0.17	4
14/6/82 - 20/6/82	105	2.85	26.9	0.05	4	172	1.92	30.9	0.04	9
21/6/82 - 27/6/82	34	0.72	4.88	0.04	21	120	1.82	28.5	0.08	4
28/6/82 - 4/7/82	75	2.39	11.2	0.05	25	120	1.63	24.6	0.09	5
5/7/82 - 11/7/82	214	0.29	2.9	0.14	18	215	1.44	28.7	0.11	5
12/7/82 - 18/7/82	287	0.44	2.4	0.11	27	147	1.42	27.4	0.11	9
19/7/82 - 25/7/82	212	0.71	9.6	0.14	25	168	0.84	20.0	0.11	6
26/7/82 - 1/8/82	184	0.33	2.4	0.14	30	136	0.90	26.9	0.11	12
2/8/82 - 8/8/82	169	0.52	2.9	0.14	31	117	0.87	26.0	0.11	10
9/8/82 - 15/8/82	168	0.34	N/A	0.14	27	100	0.81	25.1	0.07	7
16/8/82 - 22/8/82	157	0.63	2.68	0.07	19	80	1.03	23.96	0.07	7
23/8/82 - 29/8/82	183	1.11	2.48	0.05	25	86	1.13	23.75	0.03	9
30/8/82 - 5/9/82	230	0.61	2.54	0.06	22	93	1.10	22.54	0.09	5
6/9/82 - 12/9/82	226	1.15	3.46	0.34	25	97	1.10	23.5	0.29	8
13/9/82 - 19/9/82	294	0.35	3.02	0.09	23	117	1.57	21.9	0.08	10
20/9/82 - 26/9/82	246	0.56	4.94	0.08	21	149	0.93	18.6	0.26	9
27/9/82 - 3/10/82	273	0.27	2.31	0.03	25	106	0.96	23.2	0.23	8
4/10/82 - 10/10/82	306	0.61	1.94	N/A	37	135	1.38	24.5	0.18	5
11/10/82 - 9/11/82	1,277	0.60	4.04	0.10	26	688	0.75	20.9	0.30	12
8/11/82 - 5/12/82	1,275	0.80	5.1	0.05	33	534	0.90	19.7	0.20	11
6/12/82 - 10/1/83	882	0.85	4.7	0.05	30	424	0.95	18.9	0.10	5
11/1/83 - 30/1/83	338	0.61	2.07	0.01	24	221	2.34	24.3	0.10	6
31/1/83 - 27/2/83	239	1.71	13.4	0.04	27	289	1.50	9.6	0.40	16
28/2/83 - 27/3/83	313	1.15	4.4	0.02	42	281	1.19	18.2	0.20	12
28/3/83 - 24/4/83	198	1.00	14.4	0.07	47	215	1.51	15.9	0.03	17
25/4/83 - 22/5/83	914	0.89	7.45	0.06	181	605	1.43	15.9	<0.01	23
23/5/83 - 19/6/83	604	1.68	6.3	0.13	329	571	1.50	17.2	0.03	18
20/6/83 - 11/7/83	315	0.78	5.3	0.08	250	313	1.16	15.5	0.03	12
12/7/83	57*	0.4	4.63	0.03	276	12*	1.12	18.7	0.01	10

* See pg. H-2

EFFLUENT SOLUTIONS-FLOWS AND ANALYSES

	Seepage					Runoff				
Sample Period	Flow L	U mg/L	As mg/L	Ni mg/L	Ra pCi/L	Flow L	U mg/L	As mg/L	Ni mg/L	Ra pCi/L
13/7/83	973*	5.7	59.7	0.44	203	416*	0.38	4.94	0.01	15
14/7/83	994*	3.73	41.8	0.35	192	828*	0.22	4.47	0.02	7
15/7/83	726*	4.65	50.1	0.58	325	604*	0.21	7.50	0.21	9
18/7/83	472*	1.86	24.5	0.17	152	68*	0.21	10.28	0.01	9
22/10/83 - 31/10/83	398	1.8	12.	0.22	-	178	1.2	7.3	0.11	-
1/11/83 - 30/11/83	960	1.4	9.5	0.33	38.7	480	0.82	7.1	0.64	25.3
1/12/83 - 31/12/83	1213	1.0	8.5	0.14	41.6	625	0.80	9.4	0.02	110.0
1/1/84 - 31/1/84	1250	1.1	9.5	0.12	65.7	638	0.85	12	0.03	23.9
1/2/84 - 29/2/84	1140	1.2	11	0.10	125.5	584	0.87	12	0.01	67.2
1/3/84 - 31/3/84	1327	1.0	11	0.10	19.0	882	0.80	13	0.03	18.7
1/4/84 - 30/4/84	839	1.1	12	0.10	69.3	581	0.67	12	0.04	17.0
1/5/84 - 31/5/84	1024	1.1	12	0.10	76.5	651	0.48	11	0.06	26.3

* Volumes recorded during the flood period are questionable.

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APPENDIX I

PHYSICAL CHARACTERISTICS OF CORE SEGMENTS TESTED BY GOLDER ASSOCIATES

SUMMARY OF CONSTANT HEAD PERMEABILITY RESULTS

DATE RECEIVED	TEST NO.	GRID NO.	COEFFICIENT OF PERMEABILITY (cm/sec.)	HYDRAULIC GRADIENT
March 31, 1982	T-5	B-2	1.8×10^{-5}	4.7
	T-6	B-8	1.5×10^{-5}	6.3
	T-7	G-1	2.4×10^{-5}	10.9
	T-8	G-9	5.1×10^{-6}	10.9

April 19, 1982

821-1105

Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

June 24, 1982 Our ref: 821-1105

Ontario Research Foundation
Sheridan Park
MISSISSAUGA, Ontario
L5K 1B3

ATTENTION: Dr. L. Lakshmanan

RE: COEFFICIENT OF PERMEABILITY
TAILINGS RESEARCH
P.O. No. 18808

Dear Sirs:

This letter reports the results of the coefficient of permeability tests which have been carried out on samples received at our laboratory on May 31, 1982.

On March 31, 1982, four samples were taken from the tailings bed by a member of our staff. The results of those tests were reported in our letter of April 19, 1982.

On May 31, 1982, it was reported by your office that there had been a misunderstanding on the test procedure, and it was requested that new samples be taken from the tailings bed and the tests repeated.

Each of the original four samples, taken March 31, 1982, were tested as one sample, measuring the permeability along the entire length of the sample, whereas they should have been cut into approximately 1 to 2 inch sections throughout the length. This is the procedure that has been followed on the samples taken on May 31, 1982.

The results of these tests are summarized on the attached Table 1. The testing on sample T-12, H-1 is still to be completed, and these results will be forwarded to you as soon as they become available.

..2

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We trust that this information is sufficient for your immediate purposes. If you have any questions regarding these results, please call us.

Yours truly,

GOLDER ASSOCIATES

F A Rydgren

F. A. Rydgren

FAR/jm

Enc. Table 1

SUMMARY OF CONSTANT HEAD PERMEABILITY TEST RESULTS

DATE RECEIVED	TEST NO.	GRID NO.	SAMPLE DEPTH* (in.)	HYDRAULIC GRADIENT	COEFFICIENT OF PERMEABILITY (cm/sec.)
1982					
May 31	T-9	B-3	2-4	9.1	8.3×10^{-6}
			4-7	10.0	3.4×10^{-6}
			7-9	15.0	6.3×10^{-6}
			9-11	13.3	1.2×10^{-7}
			11-13	14.1	2.3×10^{-5}
May 31	T-10	B-7	0-2.75	20.0	3.1×10^{-5}
			2.75-5.25	25.5	4.6×10^{-6}
			5.25-6.75	52.0	1.0×10^{-6}
			6.75-8.5	50.3	3.9×10^{-7}
			8.5 -10	80.8	8.0×10^{-6}
May 31	T-11	H-9	0-2	12.3	2.0×10^{-6}
			2-4	15.0	1.9×10^{-6}
			4-5.5	21.0	4.7×10^{-6}
			5.5-7	17.2	6.2×10^{-6}
			7-9	15.4	8.1×10^{-6}

*Depths measured from top of sample

TESTS CARRIED OUT USING THE MERCURY/WATER TRIAXIAL CONSTANT HEAD APPARATUS.

Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

July 15, 1982 Our ref: 821-1105

Ontario Research Foundation
Sheridan Park
MISSISSAUGA, Ontario
L5K 1B3

ATTENTION: Dr. L. Lakshmanan

RE: COEFFICIENT OF PERMEABILITY
TAILINGS RESEARCH
P.O. No. 18808

Dear Sirs:

This letter reports the results of the coefficient of permeability tests carried out on sample T-12, H-1, received at our laboratory on May 31, 1982.

The results of these tests are summarized on Table 1, which is an addendum to our letter of June 24, 1982.

This letter report concludes the testing program for your purchase order No. 18808. A total of 22 tests have been carried out at a cost of $1,100; therefore, we shall issue a credit note for $100 against the prepaid purchase order.

We trust that this information is sufficient for your immediate purposes. If you have any questions regarding these results, please call us.

Yours truly,

GOLDER ASSOCIATES

F. A. Rydgren

FAR/jm

Enc. Table 1

(ADDENDUM)

SUMMARY OF CONSTANT HEAD PERMEABILITY TEST RESULTS

DATE RECEIVED	TEST NO.	GRID NO.	SAMPLE DEPTH* (in.)	HYDRAULIC GRADIENT	COEFFICIENT OF PERMEABILITY (cm/sec.)
(1982)					
May 31	T-12	H-1	0.75-3	65.3	1.4×10^{-5}
			3-5.5	81.7	3.2×10^{-6}
			5.75-6.5	84.3	5.9×10^{-6}

*Depths measured from top of sample

TESTS CARRIED OUT USING THE MERCURY/WATER TRIAXIAL
CONSTANT HEAD APPARATUS.

July 15, 1982

Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

August 12, 1982 Our ref: 821-1105-1

Ontario Research Foundation
Sheridan Park
MISSISSAUGA, Ontario
L5K 1B3

ATTENTION: Dr. L. Lakshmanan

RE: PERMEABILITY AND TRIAXIAL TESTING
TAILINGS RESEARCH
P.O. No. 20407

Dear Sirs:

This letter reports the results of the coefficient of permeability and quick undrained triaxial tests which have been carried out on samples received at our laboratory between July 24 and July 27, 1982.

The results of the permeability tests carried out to date are summarized on the attached Table 1. The tests on sample number T-16B are still to be completed, and these results will be forwarded to you as soon as they become available.

The quick undrained triaxial test results are summarized on the attached Tables 2 to 5, inclusive.

We trust that this information is sufficient for your immediate purposes. If you have any questions regarding these results, please call us.

Yours truly,

GOLDER ASSOCIATES

F. A. Rydgren

FAR/jm

Enc. Tables 1 to 5

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TABLE 1

SUMMARY OF CONSTANT HEAD PERMEABILITY TEST RESULTS

DATE RECEIVED (1982)	TEST NO.	GRID NO.	SAMPLE DEPTH* (in.)	HYDRAULIC GRADIENT	COEFFICIENT OF PERMEABILITY (cm/sec.)
July 24	T-13B	G-1	1-3	22.3	7.0×10^{-7}
		3 in. S	3-5	27.6	9.0×10^{-7}
		3 in. E	5-7	18.6	4.6×10^{-6}
			7-9	22.0	1.3×10^{-6}
			9-11	23.6	2.0×10^{-6}
			11-13	20.8	2.7×10^{-6}
July 24	T-14B	C-1	0-5	Not Tested	
		3 in. S	5-7	19.4	9.6×10^{-6}
			7-9	19.0	1.1×10^{-5}
			9-11	19.8	6.7×10^{-6}
			11-13	16.6	6.6×10^{-6}
			13-15	16.4	5.6×10^{-6}
			15-17	18.1	3.0×10^{-6}
July 27	T-15B	C-9	0-1	Not Tested	
		3 in. S	1-3.5	14.2	9.1×10^{-6}
			3.5-6	15.4	2.5×10^{-6}
			6-8.5	16.1	5.2×10^{-6}
			8.5-11	13.3	8.0×10^{-6}
			11-13	20.9	7.1×10^{-6}
			13-16	10.2	1.4×10^{-6}

*Depths measured from top of sample.

TESTS CARRIED OUT USING THE MERCURY/WATER
TRIAXIAL CONSTANT HEAD APPARATUS.

TABLE 2

SUMMARY OF QUICK TRIAXIAL ATTERBERG AND UNIT WEIGHT RESULTS

TEST No.	T-13C	T-13C	T-13C	
GRID No.	G-1 6 in. South	-	-	
DEPTH in.	9-13	5-9	1-5	
WATER CONTENT %	166.9	146.3	102.6	
LIQUID LIMIT %				
PLASTIC LIMIT %				
UNIT WEIGHT lb/cu.ft.	81.4	82.0	91.9	
CELL PRESSURE lb/sq.in.	5.0	10.0	20.0	
AXIAL STRAIN %	COMPRESSIVE STRESS (lb/sq.in.)	COMPRESSIVE STRESS (lb/sq.in.)	COMPRESSIVE STRESS (lb/sq.in.)	COMPRESSIVE STRESS (lb/sq.in.)
0.25	0.8	1.0	0.6	
0.5	1.1	1.3	0.7	
0.75	1.4	1.7	0.9	
1	1.6	1.9	1.0	
1.5	1.9	2.2	1.2	
2	2.2	2.7	1.3	
3	2.8	2.9	1.5	
4	3.1	3.1	1.7	
5	3.2	3.2	1.8	
6	3.4	3.4	1.9	
7	3.4	3.4	1.9	
8	3.5	3.5	2.0	
9	3.6	3.5	2.1	
10	3.6	3.6	2.1	
11	3.6	3.6	2.1	
12	3.6	3.6	2.1	
13	3.7	3.6	2.1	
14	3.7	3.6	2.1	
15	3.7	3.6	2.1	
16	3.7	3.6	2.1	
17	3.6	3.6	2.1	
18	3.6	3.5	2.1	
19	3.6	3.5	2.2	
20	3.6	3.5	2.2	

TABLE 3

SUMMARY OF QUICK TRIAXIAL ATTERBERG AND UNIT WEIGHT RESULTS

TEST No.	T-14C	T-14C	T-14C	
GRID No.	C-1 3 in. North	-	-	
DEPTH in.	2-6	7-11	11-15	
WATER CONTENT %	93.1	94.2	71.4	
LIQUID LIMIT %				
PLASTIC LIMIT %				
UNIT WEIGHT lb/cu.ft.	91.6	91.5	97.9	
CELL PRESSURE lb/sq.in.	5.0	10.0	20.0	
AXIAL STRAIN %	COMPRESSIVE STRESS (lb/sq.in.)	COMPRESSIVE STRESS (lb/sq.in.)	COMPRESSIVE STRESS (lb/sq.in.)	COMPRESSIVE STRESS (lb/sq.in.)
0.25	0.7	0.6	0.6	
0.5	1.0	0.9	0.8	
0.75	1.2	1.1	1.1	
1	1.4	1.3	1.3	
1.5	1.6	1.5	1.6	
2	1.9	1.8	1.9	
3	2.2	2.3	2.3	
4	2.3	2.5	2.7	
5	2.4	2.7	2.8	
6	2.5	2.8	2.9	
7	2.5	2.9	3.0	
8	2.5	3.0	3.0	
9	2.5	3.1	3.1	
10	2.5	3.1	3.1	
11	2.6	3.1	3.1	
12	2.6	3.1	3.2	
13	2.7	3.1	3.2	
14	2.7	3.2	3.2	
15	2.8	3.2	3.2	
16	2.8	3.3	3.2	
17	2.9	3.3	3.2	
18	2.9	3.4	3.2	
19	2.9	3.4	3.3	
20	2.9	3.4	3.2	

TABLE 4

SUMMARY OF QUICK TRIAXIAL ATTERBERG AND UNIT WEIGHT RESULTS

TEST No.	T-15C	T-15C	T-15C	
GRID No.	C-9 3 in. North	-	-	
DEPTH in.	12-18	6-12	0-6	
WATER CONTENT %	77.6	164.1	87.1	
LIQUID LIMIT %				
PLASTIC LIMIT %				
UNIT WEIGHT lb/cu.ft.	93.2	87.9	63.4	
CELL PRESSURE lb/sq.in.	5.0	10.0	20.0	
AXIAL STRAIN %	COMPRESSIVE STRESS (lb/sq.in.)	COMPRESSIVE STRESS (lb/sq.in.)	COMPRESSIVE STRESS (lb/sq.in.)	COMPRESSIVE STRESS (lb/sq.in.)
0.25	0.3	0.4	0.5	
0.5	0.5	0.5	0.7	
0.75	0.6	0.6	0.8	
1	0.9	0.7	0.9	
1.5	1.2	0.9	1.2	
2	1.5	1.1	1.4	
3	2.0	1.5	1.6	
4	2.3	1.8	1.7	
5	2.5	1.9	1.8	
6	2.7	2.0	1.8	
7	2.8	2.1	1.9	
8	3.0	2.2	1.9	
9	3.1	2.3	1.9	
10	3.2	2.2	2.0	
11	3.3	2.3	2.0	
12	3.4	2.3	1.9	
13	3.4	2.4	1.9	
14	3.5	2.4	1.9	
15	3.6	2.4	2.0	
16	3.6	2.5	2.0	
17	3.7	2.5	2.0	
18	3.7	2.5	2.0	
19	3.7	2.4	2.0	
20	3.7	2.5	2.0	

TABLE 5

SUMMARY OF QUICK TRIAXIAL ATTERBERG AND UNIT WEIGHT RESULTS

TEST No.	T-16C	T-16C	T-16C	
GRID No.	G-9 12 in.W-3 in.N	-	-	
DEPTH in.	0-4	4-8	8-12	
WATER CONTENT %	141.5	134.5	112.3	
LIQUID LIMIT %				
PLASTIC LIMIT %				
UNIT WEIGHT lb/cu.ft.	82.1	80.9	80.9	
CELL PRESSURE lb/sq.in.	5.0	10.0	20.0	
AXIAL STRAIN %	COMPRESSIVE STRESS (lb/sq.in.)	COMPRESSIVE STRESS (lb/sq.in.)	COMPRESSIVE STRESS (lb/sq.in.)	COMPRESSIVE STRESS (lb/sq.in.)
0.25	0.2	0.2	0.4	
0.5	0.3	0.4	0.5	
0.75	0.4	0.5	0.6	
1	0.5	0.6	0.7	
1.5	0.6	0.8	0.9	
2	0.7	1.0	1.0	
3	1.0	1.3	1.3	
4	1.2	1.6	1.5	
5	1.3	1.7	1.7	
6	1.4	1.8	1.9	
7	1.5	1.9	2.0	
8	1.5	2.0	2.1	
9	1.5	2.1	2.2	
10	1.6	2.2	2.3	
11	1.6	2.2	2.3	
12	1.6	2.3	2.3	
13	1.6	2.3	2.4	
14	1.6	2.4	2.4	
15	1.7	2.5	2.4	
16	1.6	2.5	2.5	
17	1.6	2.5	2.5	
18	1.6	2.6	2.6	
19	1.6	2.6	2.5	
20	1.6	2.6	2.6	

Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

September 15, 1982 Our ref: 821-1105-1

Ontario Research Foundation
Sheridan Park
MISSISSAUGA, Ontario
L5K 1B3

ATTENTION: Dr. L. Lakshmanan

RE: COEFFICIENT OF PERMEABILITY
TAILINGS RESEARCH
P.O. No. 20407

Dear Sirs:

This letter reports the results of the coefficient of permeability tests carried out on sample T-16B, G-9, received at our laboratory on July 27, 1982.

The results of these tests are summarized on Table 1, which is an addendum to our letter of August 12, 1982. This letter concludes the testing program for your Purchase Order No. 20407.

We trust that this information is sufficient for your immediate purposes. If you have any questions regarding these results, please call us.

Yours truly,

GOLDER ASSOCIATES

F.A. Rydgren
F. A. Rydgren

FAR/jm

Enc. Table 1

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TABLE 1

ADDENDUM
SUMMARY OF CONSTANT HEAD PERMEABILITY TEST RESULTS

DATE RECEIVED (1982)	TEST NO.	GRID NO.	SAMPLE DEPTH* (in.)	HYDRAULIC GRADIENT	COEFFICIENT OF PERMEABILITY (cm/sec.)
July 27	T-16B	G-9	1-3	17.8	5.7×10^{-7}
		12 in. W	3-5	27.5	3.5×10^{-6}
		3 in. S	5-7	24.9	8.7×10^{-6}
			7-9	18.1	1.2×10^{-6}
			9-11	22.9	4.7×10^{-6}
			11-13	26.9	8.8×10^{-6}

*Depths measured from top of sample.

TESTS CARRIED OUT USING THE MERCURY/WATER
TRIAXIAL CONSTANT HEAD APPARATUS.

Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

TRANSMITTAL LETTER

To Ontario Research Foundation
Sheridan Park
MISSISSAUGA, Ontario
L5K 1B3

ATTENTION: Dr. V. I. Lakshmanan

Date February 11, 1983
Project No. 821-1105-2

Your Purchase Order No. 22528

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Quantity	Item	Description
1	TABLES 1 to 5	Laboratory Test Results Quick Triaxial Constant Head Permeability Porosity

Remarks

Per F. A. Rydgren
F. A. Rydgren

TABLE 1

SUMMARY OF QUICK TRIAXIAL ATTERBERG AND UNIT WEIGHT RESULTS

TEST NO.	T-17B	T-18B	T-19B	T-20B
GRID NO.	C2 6N-6W	C7 6N-6W	G2 6N-6E	G7 6N-6E
DEPTH cm	27.9-38.1	0-10	27.8-38.0	16.4-26.8
AFTER TEST WATER CONTENT %	70.9	90.0	156.5	94.3
LIQUID LIMIT %	-	-	-	-
PLASTIC LIMIT %	-	-	-	-
UNIT WEIGHT Mg/m^3	1.583	1.460	1.364	1.442
CELL PRESSURE lb/sq.in.	5.0	5.0	5.0	5.0
AXIAL STRAIN %	COMPRESSIVE STRESS (lb/sq.in.)	COMPRESSIVE STRESS (lb/sq.in.)	COMPRESSIVE STRESS (lb/sq.in.)	COMPRESSIVE STRESS (lb/sq.in.)
0.2	0.8	0.3	0.1	0.4
0.5	1.1	0.5	0.5	0.5
0.7	1.3	0.6	0.8	0.5
1.0	1.6	0.7	1.0	0.6
1.5	1.9	0.9	1.3	0.6
2.0	2.4	1.2	1.6	0.7
3.0	3.1	1.5	2.0	0.8
4.0	3.6	1.8	2.3	0.9
5.0	4.0	2.0	2.5	1.0
6.0	4.1	2.1	2.6	1.1
7.0	4.3	2.2	2.8	1.2
8.0	4.3	2.2	2.8	1.3
9.0	4.3	2.3	2.8	1.4
10.0	4.4	2.3	2.8	1.4
11.0	4.6	2.4	2.8	1.5
12.0	4.6	2.4	2.8	1.6
13.0	4.6	2.4	2.9	1.7
14.0	4.6	2.4	2.9	1.7
15.0	4.8	2.4	2.9	1.7
16.0	4.7	2.5	3.0	1.7
17.0	4.9	2.5	3.0	1.7
18.0	5.0	2.5	3.0	1.8
19.0	5.0	2.5	3.0	1.8
20.0	5.0	2.5	3.1	1.8

TABLE 2

SUMMARY OF CONSTANT HEAD PERMEABILITY TEST RESULTS

GRID NO. C2 6N-6W

TEST NO. T-17B

SAMPLE DEPTH* cm	7.6-12.7	14.0-19.1	19.1-24.1	24.1-27.9	38.1-43.2	43.2-49.5
WATER CONTENT, Initial %	86.3	126.6	115.1	109.4	78.2	117.8
WATER CONTENT, Final %	75.2	118.8	105.2	95.4	83.9	106.7
DRY DENSITY Mg/m^3	0.83	0.64	0.68	0.75	0.85	0.68

SAMPLE VOLUME cm^3	108.90	94.86	73.81	75.17	91.39	115.53
DRY WEIGHT g	90.7	60.2	50.4	56.0	77.5	77.9
SPECIFIC GRAVITY	2.60	2.60	2.60	2.60	2.60	2.60
VOLUME SOLIDS cm^3	34.88	23.15	19.38	21.54	29.81	29.96
VOID RATIO e	2.122	3.097	2.808	2.490	2.066	2.856
POROSITY n	0.679	0.756	0.737	0.713	0.674	0.741

HEAD PRESSURE cm	178.7	173.1	175.9	153.7	162.0	210.5
HYDRAULIC GRADIENT Q	31.7	35.3	46.0	39.7	34.2	35.2
COEFFICIENT OF PERMEABILITY, k cm/s	$7x10^{-6}$	$1.3x10^{-6}$	$6.2x10^{-6}$	$6.0x10^{-6}$	$4.5x10^{-6}$	$6.5x10^{-6}$

*Depth measured from top of sample

TESTS CARRIED OUT USING THE MERCURY/WATER TRIAXIAL CONSTANT HEAD APPARATUS.

TABLE 3

SUMMARY OF CONSTANT HEAD PERMEABILITY TEST RESULTS

GRID NO. C7 6N-6W

TEST NO. T-18B

SAMPLE DEPTH* cm	10.1-15.2	15.2-20.3	20.3-25.4	30.5-35.5	35.5-38.1	
WATER CONTENT, Initial %	85.1	83.8	85.6	123.8	85.7	
WATER CONTENT, Final %	77.8	75.1	72.0	101.9	67.0	
DRY DENSITY Mg/m^3	0.80	0.84	0.83	0.62	0.80	

SAMPLE VOLUME cm^3	91.93	98.76	94.9	93.7	81.4	
DRY WEIGHT g	73.5	82.7	78.7	58.5	65.2	
SPECIFIC GRAVITY	2.60	2.60	2.60	2.60	2.60	
VOLUME SOLIDS cm^3	28.27	31.81	30.27	22.50	25.08	
VOID RATIO e	2.252	2.105	2.133	3.164	2.245	
POROSITY n	0.692	0.678	0.681	0.760	0.692	

HEAD PRESSURE cm	77.3	84.4	133.6	98.4	246.1	
HYDRAULIC GRADIENT Q	16.4	16.7	27.5	20.5	59.2	
COEFFICIENT OF PERMEABILITY, k cm/s	2.7×10^{-6}	3.7×10^{-6}	4.3×10^{-6}	1.0×10^{-6}	1×10^{-5}	

*Depth measured from top of sample

TESTS CARRIED OUT USING THE MERCURY/WATER TRIAXIAL CONSTANT HEAD APPARATUS.

TABLE 4

SUMMARY OF CONSTANT HEAD PERMEABILITY TEST RESULTS

GRID NO.	G2 6N-6E
TEST NO.	T-19B

SAMPLE DEPTH* cm	8.8-12.6	12.6-15.3	15.3-17.8	17.8-20.5	20.5-24.1	24.1-27.9
WATER CONTENT, Initial %	216.9	170.8	164.7	188.9	175.9	174.6
WATER CONTENT, Final %	168.4	173.9	155.6	146.3	166.1	160.2
DRY DENSITY Mg/m^3	0.41	0.48	0.50	0.48	0.46	0.48

SAMPLE VOLUME cm^3	55.15	52.52	48.30	51.44	69.34	73.04
DRY WEIGHT g	22.5	25.30	24.1	24.4	31.9	34.7
SPECIFIC GRAVITY	2.60	2.60	2.60	2.60	2.60	2.60
VOLUME SOLIDS cm^3	8.65	9.73	9.27	9.38	12.27	13.35
VOID RATIO e	46.50	42.79	39.03	42.06	57.07	59.69
POROSITY n	0.843	0.815	0.808	0.818	0.823	0.817

HEAD PRESSURE cm	131.6	173.1	152.3	161.3	171.7	173.1
HYDRAULIC GRADIENT Q	46.7	64.5	61.7	61.3	48.4	46.3
COEFFICIENT OF PERMEABILITY, k cm/s	2.7x10^{-6}	9.0x10^{-7}	2.5x10^{-6}	8.5x10^{-6}	1.0x10^{-5}	6.3x10^{-6}

*Depth measured from top of sample

TESTS CARRIED OUT USING THE MERCURY/WATER TRIAXIAL CONSTANT HEAD APPARATUS.

TABLE 5

SUMMARY OF CONSTANT HEAD PERMEABILITY TEST RESULTS

GRID NO.	G7 6N-6E
TEST NO.	T-20B

SAMPLE DEPTH* cm	8.0-11.2	11.2-13.7	13.7-16.4	26.8-31.5	31.5-34.2	34.2-38.0
WATER CONTENT, Initial %	147.7	210.3	127.5	160.0	155.6	174.5
WATER CONTENT, Final %	84.9	187.1	104.8	136.6	138.9	158.0
DRY DENSITY Mg/m^3	0.52	0.41	0.60	0.49	0.53	0.46

SAMPLE VOLUME cm^3	58.88	46.94	51.82	89.78	51.64	70.42
DRY WEIGHT g	30.4	19.4	31.3	44.3	27.5	32.60
SPECIFIC GRAVITY	2.60	2.60	2.60	2.60	2.60	2.60
VOLUME SOLIDS cm^3	11.69	7.46	12.04	17.04	10.58	12.54
VOID RATIO e	4.037	5.292	3.304	4.269	3.881	4.616
POROSITY n	0.801	0.841	0.768	0.810	0.795	0.822

HEAD PRESSURE cm	138.5	174.5	152.3	177.3	173.1	173.1
HYDRAULIC GRADIENT Q	46.0	72.7	57.5	38.6	65.6	48.1
COEFFICIENT OF PERMEABILITY, k cm/s	4.0×10^{-6}	3.8×10^{-6}	2.6×10^{-6}	3.6×10^{-7}	7.4×10^{-6}	1.0×10^{-5}

*Depth measured from top of sample

TESTS CARRIED OUT USING THE MERCURY/WATER TRIAXIAL CONSTANT HEAD APPARATUS.

February 11, 1983

Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

TRANSMITTAL LETTER

To Ontario Research Foundation
Sheridan Park
MISSISSAUGA, Ontario
L5K 1B3

Date May 25, 1983
Project No. 821-1105-3

ATTENTION: Dr. V. I. Lakshmanan

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Quantity	Item	Description
1	REVISED Tables 2 to 5, inclusive	Laboratory Test Results

Remarks

Per F. A. Rydgren

TABLE 2

SUMMARY OF CONSTANT HEAD PERMEABILITY TEST RESULTS

GRID NO. GH 2.5

TEST NO. A4741

SAMPLE DEPTH* cm	29.2-26.7	26.7-24.2	24.2-21.7	11.4-7.6	7.6-3.8	3.8-0
WATER CONTENT, Initial %	134.5	186.0	222.1	181.3	207.0	185.7
WATER CONTENT, Final %	94.0	110.3	199.5	160.2	180.7	175.6
DRY DENSITY Mg/m^3	0.58	0.45	0.39	0.46	0.42	0.44
SAMPLE VOLUME cm^3	58.45	49.58	51.64	70.59	71.25	60.87
DRY WEIGHT g	33.6	22.3	19.9	32.7	29.6	27.0
SPECIFIC GRAVITY	2.60	2.60	2.60	2.60	2.60	2.60
VOLUME SOLIDS cm^3	12.92	8.58	7.65	12.58	11.38	10.38
VOID RATIO e	3.523	4.779	5.747	4.613	5.258	4.862
POROSITY n	0.779	0.827	0.852	0.822	0.840	0.829
HEAD PRESSURE cm	207.7	126.0	127.4	117.7	221.6	134.3
HYDRAULIC GRADIENT i	69.0	49.4	47.9	32.4	60.4	42.9
COEFFICIENT OF PERMEABILITY, k cm/s	2.9×10^{-6}	3.8×10^{-8}	4.3×10^{-6}	3.0×10^{-6}	7.2×10^{-6}	6.5×10^{-6}

*Depth measured from base of sample

TESTS CARRIED OUT USING THE MERCURY/WATER TRIAXIAL CONSTANT HEAD APPARATUS.

May 24, 1983

TABLE 3

SUMMARY OF CONSTANT HEAD PERMEABILITY TEST RESULTS

GRID NO. GH 7.5

TEST NO. A4742

SAMPLE DEPTH* cm	27.9-25.4	25.4-22.9	22.9-20.4	19.0-15.3	15.3-11.5	7.6-3.8
WATER CONTENT, Initial %	182.8	166.5	116.6	138.1	109.0	147.2
WATER CONTENT, Final %	148.7	114.6	100.7	121.5	107.5	132.3
DRY DENSITY Mg/m^3	0.35	0.49	0.63	0.56	0.67	0.55

SAMPLE VOLUME cm^3	55.16	45.93	64.39	80.11	67.72	79.31
DRY WEIGHT g	19.1	22.6	40.7	44.6	45.1	43.6
SPECIFIC GRAVITY	2.60	2.60	2.60	2.60	2.60	2.60
VOLUME SOLIDS cm^3	7.35	8.69	15.65	17.15	17.35	16.77
VOID RATIO e	6.509	4.284	3.114	3.671	2.904	3.729
POROSITY n	0.867	0.811	0.757	0.786	0.744	0.789

HEAD PRESSURE cm	117.4	113.9	135.7	115.3	317.1	295.3
HYDRAULIC GRADIENT Q	41.8	48.7	41.4	28.3	91.9	73.1
COEFFICIENT OF PERMEABILITY, k cm/s	5.8×10^{-6}	1.9×10^{-6}	6×10^{-6}	1.1×10^{-7}	8.2×10^{-7}	7×10^{-6}

*Depth measured from base of sample

TESTS CARRIED OUT USING THE MERCURY/WATER TRIAXIAL CONSTANT HEAD APPARATUS.

May 24, 1983

TABLE 4

SUMMARY OF CONSTANT HEAD PERMEABILITY TEST RESULTS

GRID NO. BC 2.5

TEST NO. A4739

SAMPLE DEPTH* cm	43.2-38.1	33.0-27.9	27.9-24.1	24.1-20.3	10.2-5.1	5.1-0
WATER CONTENT, Initial %	74.8	111.5	126.4	141.8	83.4	128.2
WATER CONTENT, Final %	65.6	94.8	109.5	117.6	77.3	114.2
DRY DENSITY Mg/m^3	0.90	0.68	0.62	0.57	0.85	0.62

SAMPLE VOLUME cm^3	111.53	102.47	73.61	74.20	97.75	89.12
DRY WEIGHT g	99.8	69.7	45.3	42.5	83.0	54.8
SPECIFIC GRAVITY	2.60	2.60	2.60	2.60	2.60	2.60
VOLUME SOLIDS cm^3	38.38	26.81	17.42	16.35	31.92	21.07
VOID RATIO e	1.906	2.822	3.225	3.538	2.062	3.229
POROSITY n	0.656	0.738	0.763	0.780	0.673	0.763

HEAD PRESSURE cm	163.4	163.4	202.1	211.9	232.6	229.9
HYDRAULIC GRADIENT Q	28.7	31.3	53.9	56.1	46.7	50.6
COEFFICIENT OF PERMEABILITY, k cm/s	6.3×10^{-6}	3.5×10^{-6}	3.9×10^{-6}	4.2×10^{-6}	2.6×10^{-6}	5.0×10^{-6}

*Depth measured from base of sample

TESTS CARRIED OUT USING THE MERCURY/WATER TRIAXIAL CONSTANT HEAD APPARATUS.

May 24, 1983

TABLE 5

SUMMARY OF CONSTANT HEAD PERMEABILITY TEST RESULTS

GRID NO. BC 7.5

TEST NO. A4740

SAMPLE DEPTH* cm	45.7-40.6	30.5-26.7	16.5-12.7	12.7-8.9	8.9-5.1	5.1-2.5
WATER CONTENT, Initial %	86.6	121.0	78.4	80.5	116.9	135.0
WATER CONTENT, Final %	66.6	109.8	62.3	68.0	84.0	111.6
DRY DENSITY Mg/m^3	0.80	0.65	0.90	0.85	0.69	0.57

SAMPLE VOLUME cm^3	102.85	74.41	74.61	83.96	71.88	57.47
DRY WEIGHT g	82.6	48.1	66.8	71.3	49.3	32.8
SPECIFIC GRAVITY	2.60	2.60	2.60	2.60	2.60	2.60
VOLUME SOLIDS cm^3	31.77	18.50	25.69	27.42	18.96	12.62
VOID RATIO e	2.237	3.022	1.904	2.062	2.791	3.556
POROSITY n	0.691	0.751	0.656	0.673	0.736	0.780

HEAD PRESSURE cm	187.0	173.1	211.9	198.0	225.7	241.0
HYDRAULIC GRADIENT i	35.42	45.3	55.3	45.9	61.2	81.6
COEFFICIENT OF PERMEABILITY, k cm/s	$6.7x10^{-6}$	$4.3x10^{-7}$	$5.5x10^{-6}$	$3.6x10^{-6}$	$3.3x10^{-6}$	$3.5x10^{-6}$

*Depth measured from base of sample

TESTS CARRIED OUT USING THE MERCURY/WATER TRIAXIAL CONSTANT HEAD APPARATUS.

May 24, 1983

Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

July 5, 1983

Our ref: 821-1105-4

Ontario Research Foundation
Sheridan Park
MISSISSAUGA, Ontario
L5K 1B3

ATTENTION: Dr. V.I. Lakshmanan, P.Eng.

RE: COMPARISON OF ORF TEST RESULTS FOR
MIDWEST LAKE TO ELLIOT LAKE

Dear Sirs:

This letter presents a brief overview comparing the geotechnical properties of uranium tailings from Midwest Lake produced for a tailings test bed by the Ontario Research Foundation for Midwest Lake tailings with those of uranium tailings from Elliot Lake. This review was requested by your Dr. Lakshmanan on June 8, 1983 as a supplement to the geotechnical laboratory tests carried out by Golder Associates since March, 1982 and reported previously.

During the last 15 months, Golder Associates has carried out, at ORF's request, some 93 permeability tests on thin tailings samples extracted in thin walled sampling tubes from the test bed. The tests have been carried out in four equal batches on both tailings deposited near the side from which spigoting took place and tailings from the side from which decanting occurred. The water content, unit weight and porosity of each sample tested were also determined. Twelve gradation analyses were carried out on twelve representative samples from the final batch of 24 permeability tests.

Nineteen quick undrained triaxial tests were also performed; these tests were carried out in three batches, starting in August, 1982.

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Gradations

The results of the gradation analyses on tailings from the ORF research bed are shown on Figure 1. There is a significant difference between the percentage of sand in the coarser tailings (Grid BC) than from the side furthest away from the line of spigoting (Grid GH). However, below 0.015 mm, there appears to be no signficant difference between samples obtained from Grids BC and GH. The fact that the gradations on samples from Grid BC are gap graded suggests that although sand sized tailings were preferentially deposited near the spigot line, a certain proportion of fines was also sedimented out. This would suggest that there would not be a significant difference between the overall permeabilities of coarse and fine samples, since the permeability is generally controlled by the finer fraction of the whole sample.

Figure 2 shows a grain size distribution curve for typical unclassified mill tailings from Elliot Lake. These tailings are spigoted from a discharge point at about 33 per cent solids content into a large tailings basin (in excess of 1 mile long). Sand tailings sediment nearer the point of deposition while finer silt tailings are carried down towards the decant (see Figure 3).

The gradation ranges from the ORF Midwest Lake test bed and field samples from Elliot Lake are compared in Figure 4. It will be seen that the gradation range for Midwest Lake tailings are generally located between those of slimes and sand tailings in Elliot Lake.

The permeability of any given soil type is generally governed by the void ratio of the samples. In a saturated soil sample, the void ratio and the water content of the sample are uniquely limited. Thus, permeability can be plotted against void ratio or water content.

Summary plots indicating the variation in the silt properties of typical slimes (silt tailings) and sand tailings (deposited near the spigot point) for Elliot Lake are given in Figures 5 and 6. It will be noted that the water content of the slimes reduces rapidly in the uppermost 20 ft. of the tailings mass, as the slimes are consolidated due to the overlying weight of subsequent tailings deposited.

The results of permeability tests on ORF Midwest Lake samples are compared with the Elliot Lake tailings and the results of Krizek and Salem* (1977) on Figure 7. As shown, the coefficient of permeability decreases with decreasing void ratio. It is interesting to note that the coefficient of permeability of sand tailings for Midwest Lake is less sensitive to variations in void ratio than that of slimes, whereas in Elliot Lake the two bands are generally parallel to each other. The permeability results are also plotted against the water content of the tailings in Figure 8. The results are widely scattered. The coefficient of permeability for Midwest Lake tailings generally decreases with decreasing water content, but at any given water content, the permeability of Midwest Lake tailings would appear to be lower. Nevertheless, it should be noted that the water contents of the Midwest Lake tailings samples were generally far higher than those from Elliot Lake. This is probably due to the shallow depth of the ORF test bed. It would be interesting to obtain determinations of the coefficient of permeability of the Midwest Lake tailings under higher confining pressures.

Budgetary constraints did not permit any detailed analysis of the quick undrained triaxial tests for ORF, but the compressive stress at failure in all but one test varied between 1.7 and 3.7 lb/sq.in. (240 and 530 lb/sq.ft.). This corresponds to an undrained shear strength of 120 to 265 lb/sq.ft. From Figure 5 it will be seen that this appears to be somewhat higher than the undrained shear strength determined by in situ vane tests in Elliot Lake slimes (approximately 100 lb/sq.ft.)

---

* Krizek, R.J. and Salem, A.M. (1977), "Field Performance of a Dredging Disposal Area", Proceedings of the Conference on Geotechnical Practice for Disposal of Solid Waste Materials, The University of Michigan, June 13-15.

We trust that this letter adequately provides the brief overview you requested comparing ORF test results for Midwest Lake to those of Elliot Lake. If you have any questions concerning this letter, please do not hesitate to call us.

Yours truly,

GOLDER ASSOCIATES

Taechul Kim

Tae C. Kim, P.Eng.

Denys W Reades

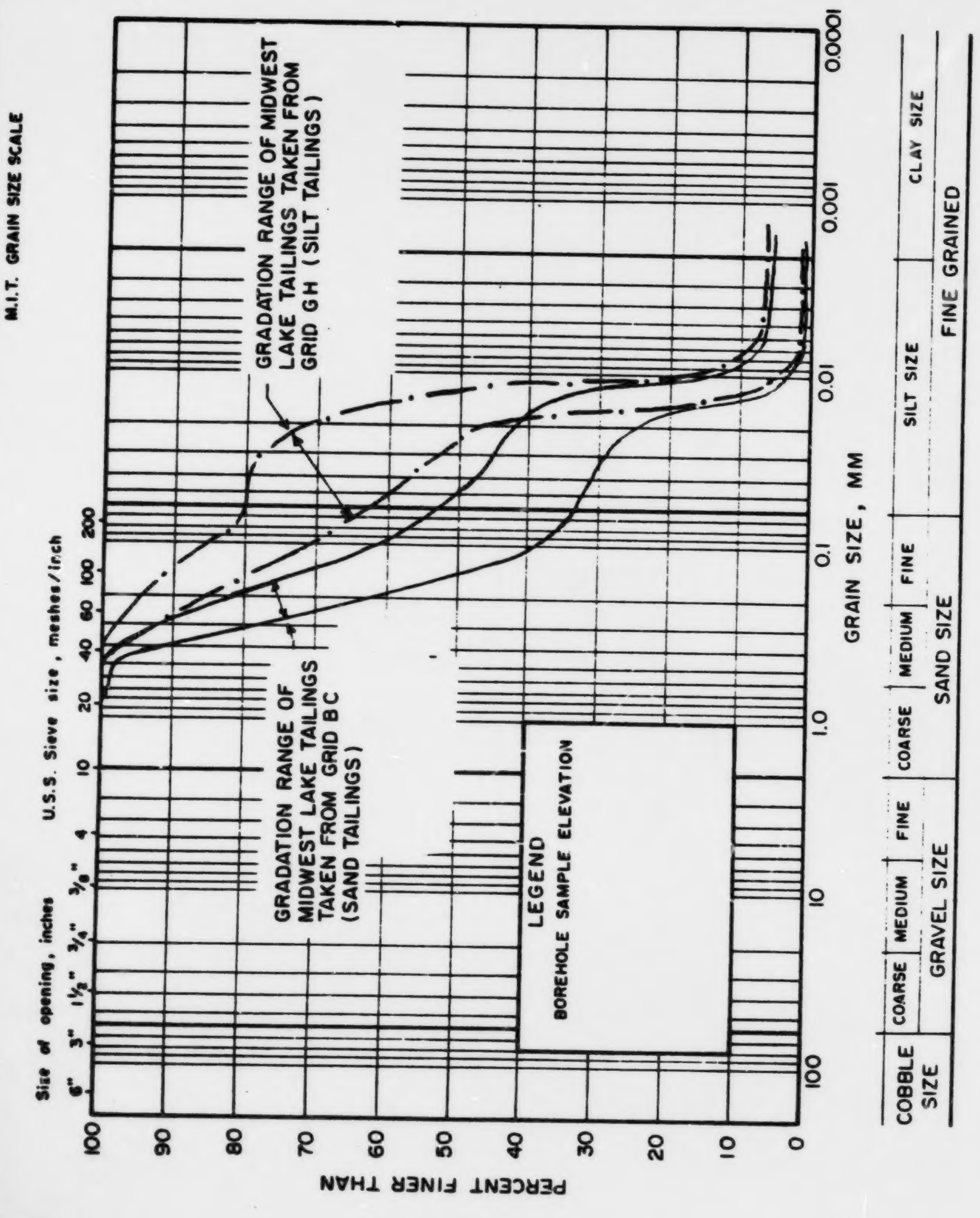
Denys W. Reades, P.Eng.

TCK/DWR/pb

Encs.

GRAIN SIZE DISTRIBUTION
MIDWEST LAKE TAILINGS

FIGURE 1



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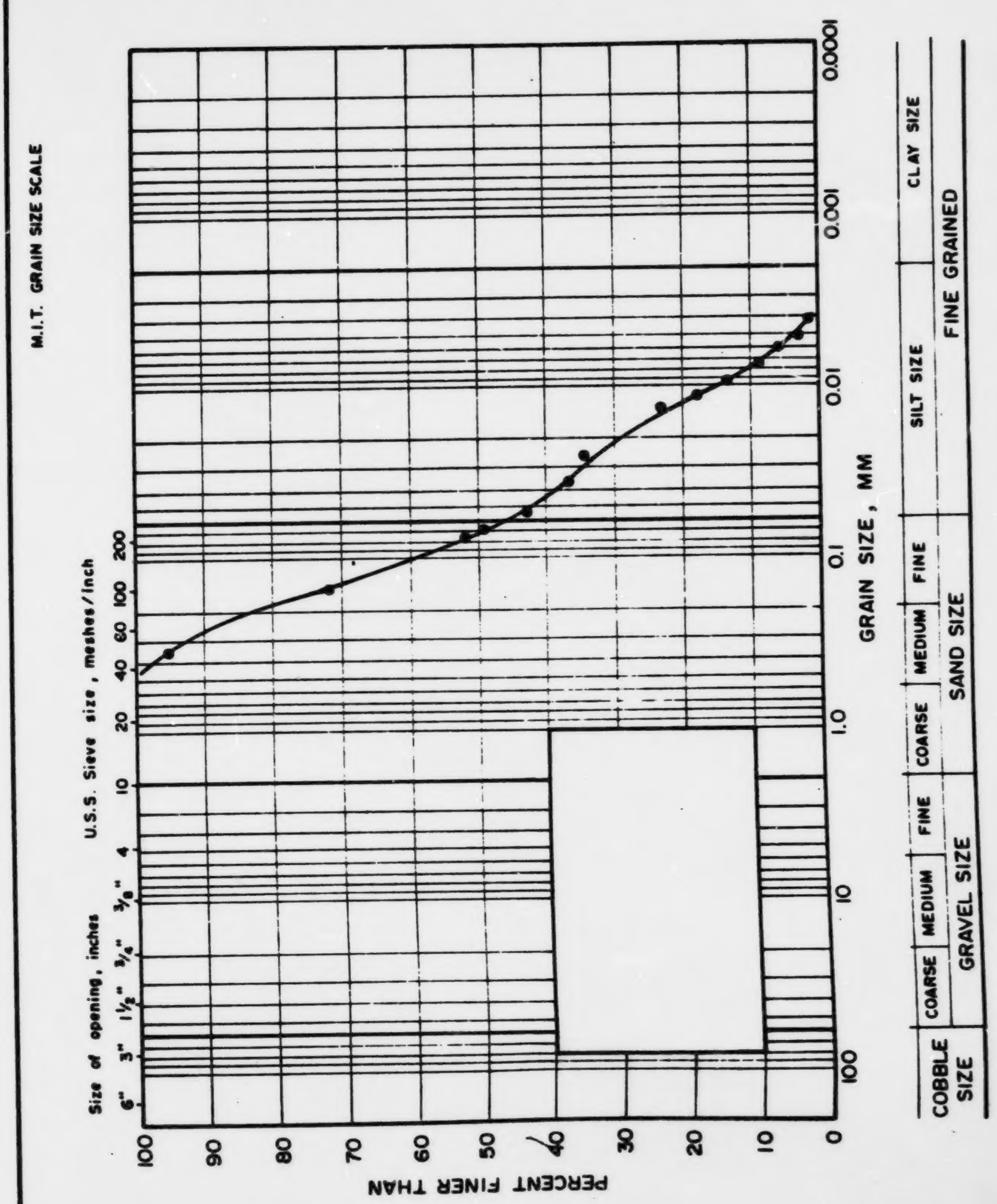
GRAIN SIZE DISTRIBUTION
TYPICAL UNCLASSIFIED MILL TAILINGS
(ELLIOT LAKE)

FIGURE 2



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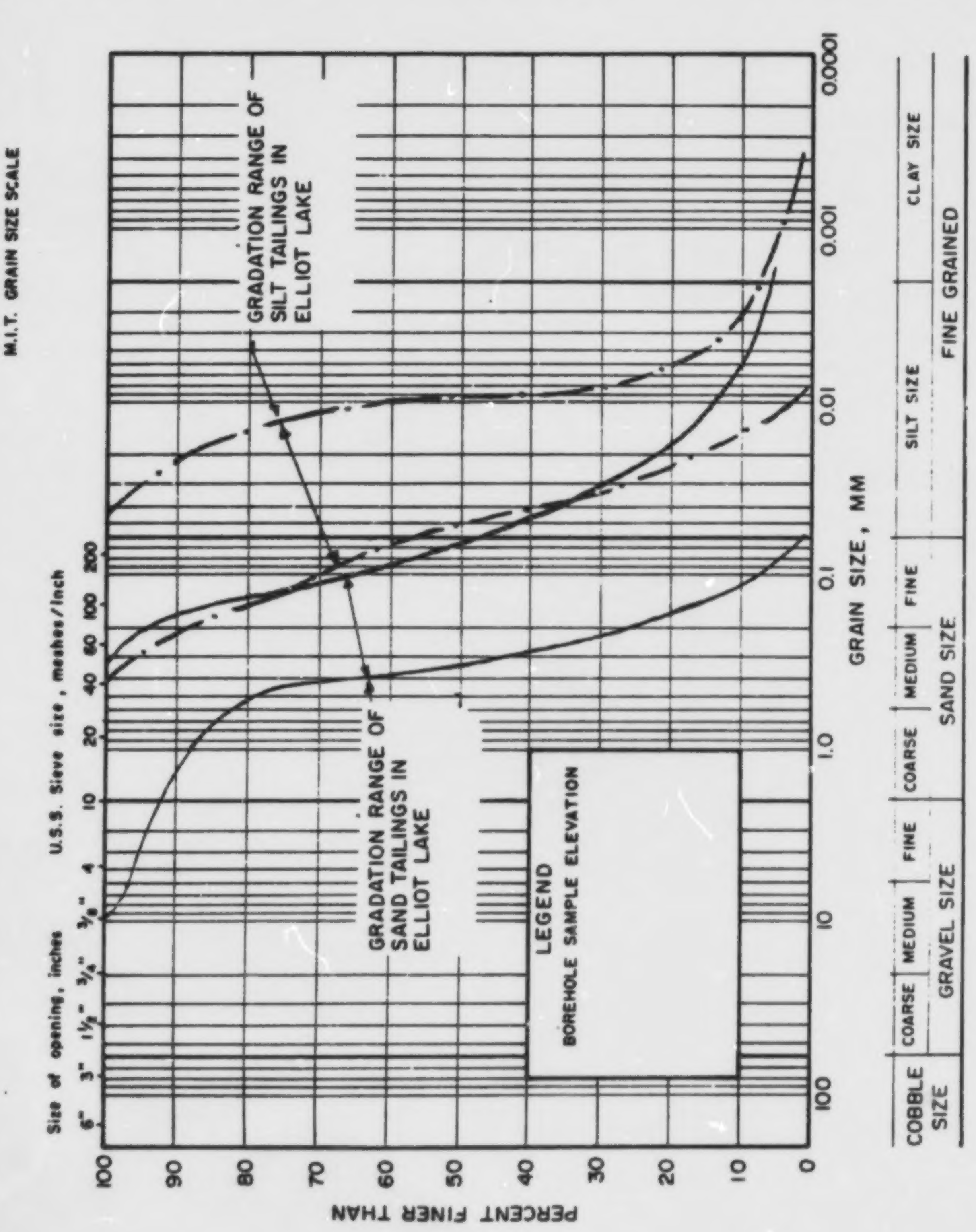
GRAIN SIZE DISTRIBUTION
ELLIOT LAKE TAILINGS

FIGURE 3



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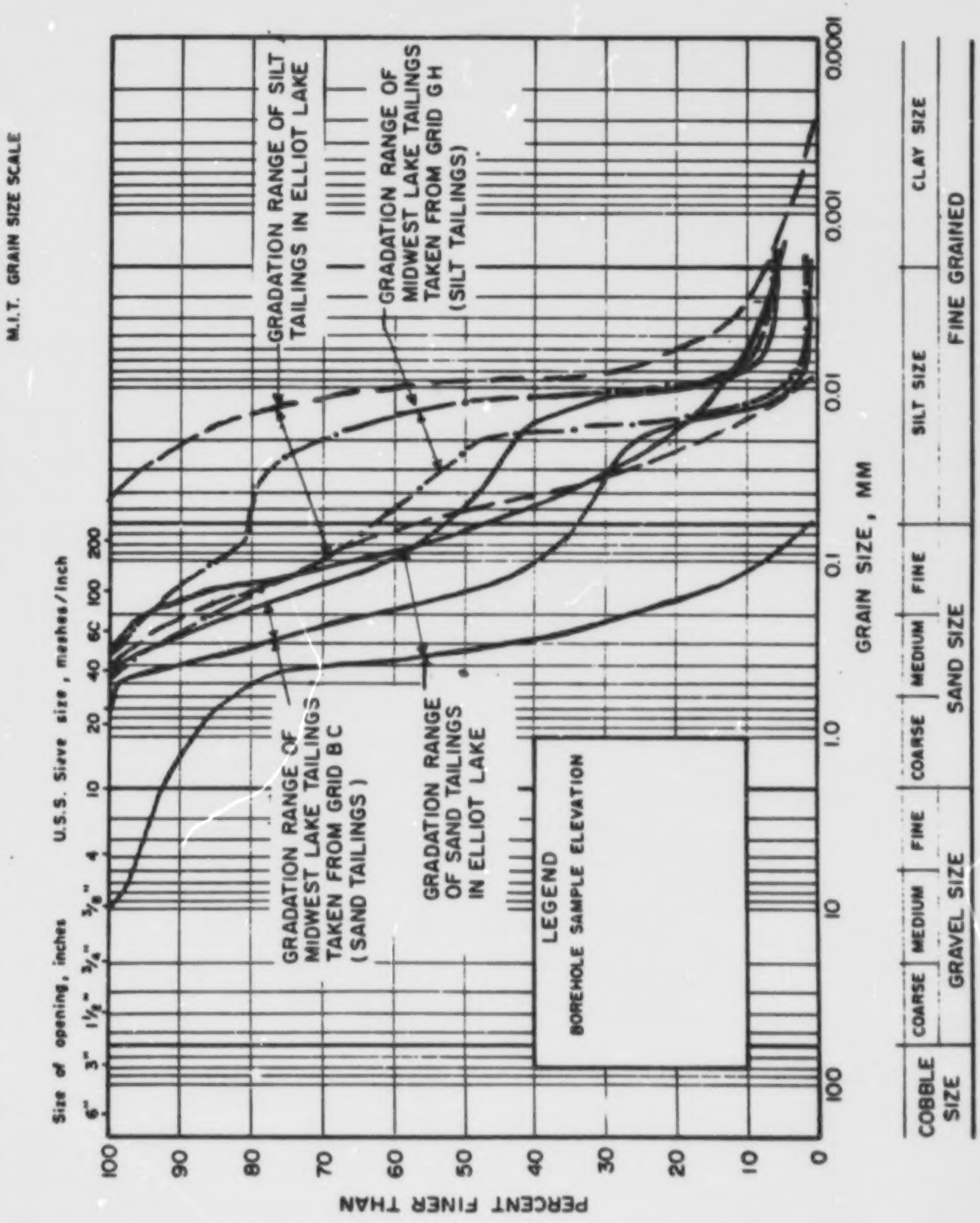
GRAIN SIZE DISTRIBUTION

FIGURE 4



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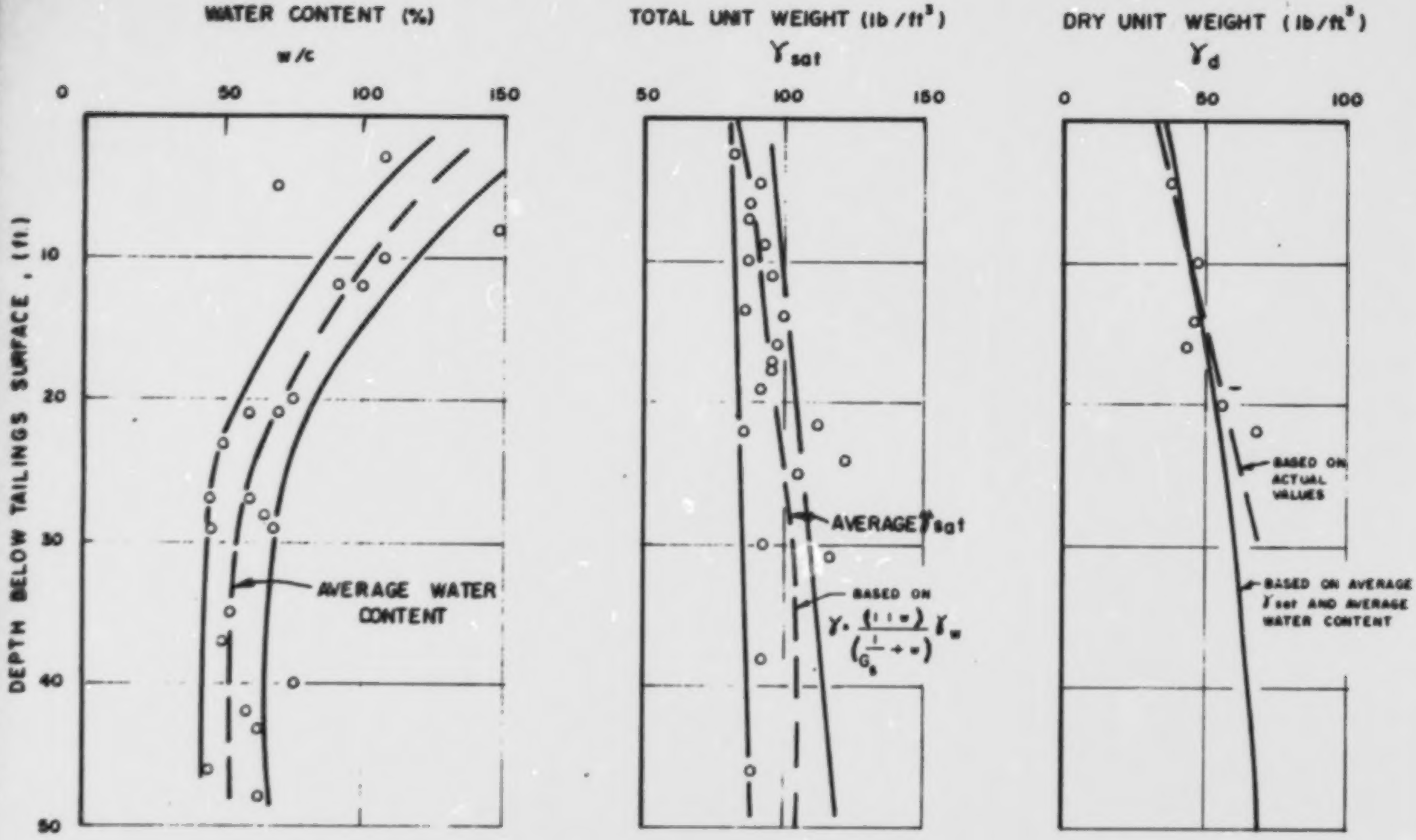

Date JULY 7, 1983
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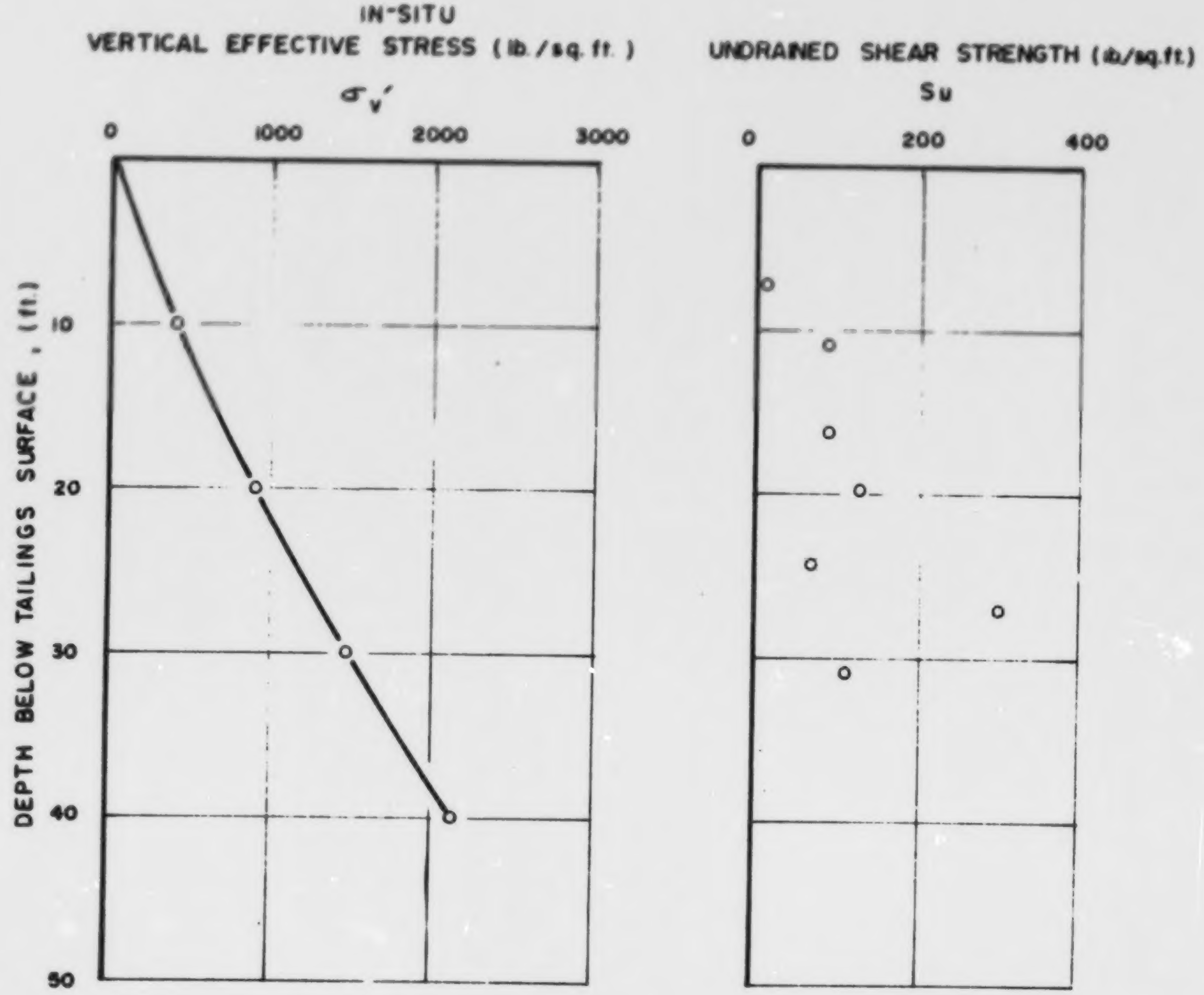
Drawn G P
Chkd

IN-SITU PROPERTIES OF
TYPICAL SLIMES, ELLIOT LAKE

FIGURE 5



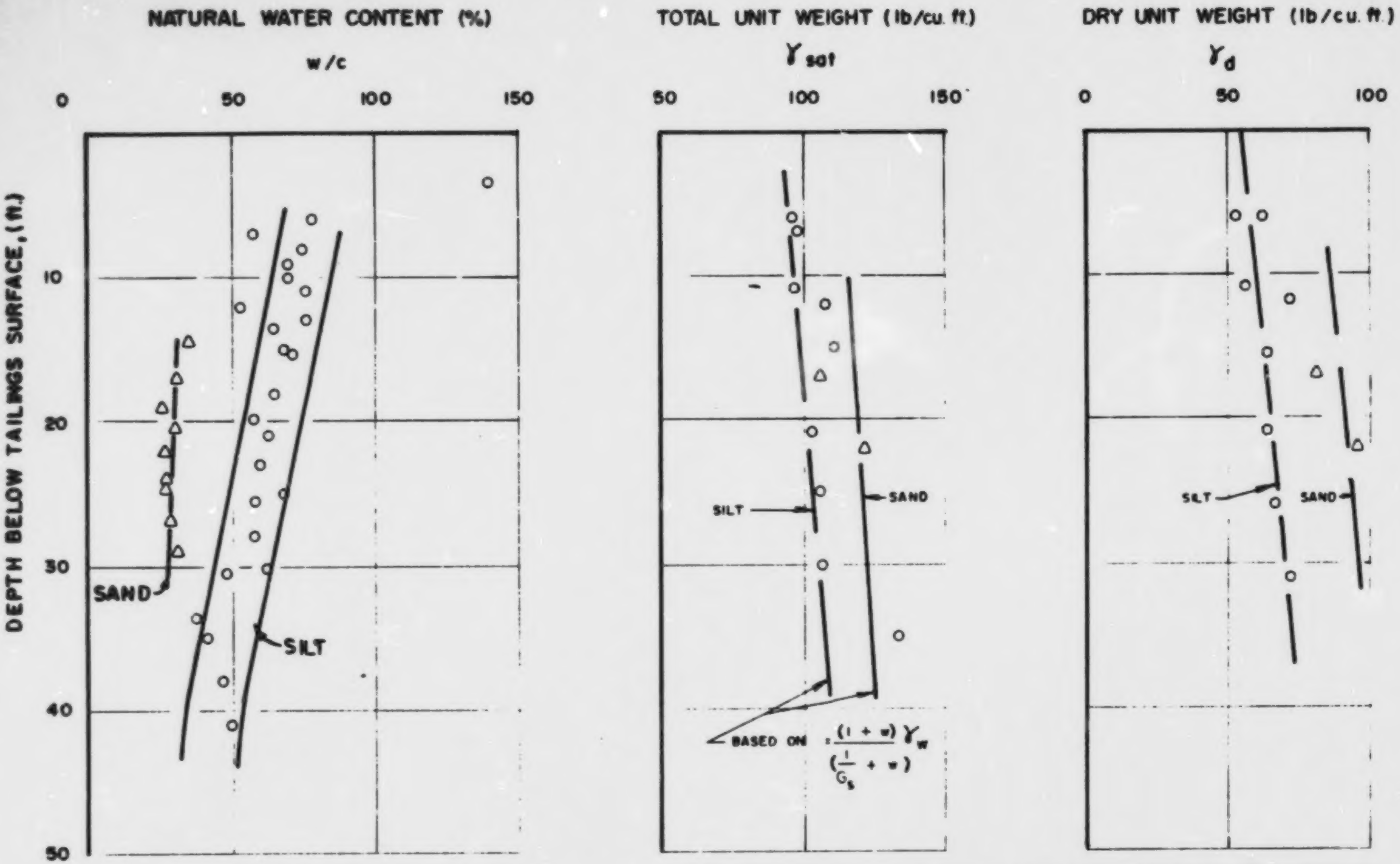
Date JULY 7, 1983
Project 821-1105-4

Golder Associates

Drawn G.P.
Chkd

IN-SITU PROPERTIES OF
TYPICAL SLIMES, ELLIOT LAKE

FIGURE 5
(cont)



Date JULY 7, 1983
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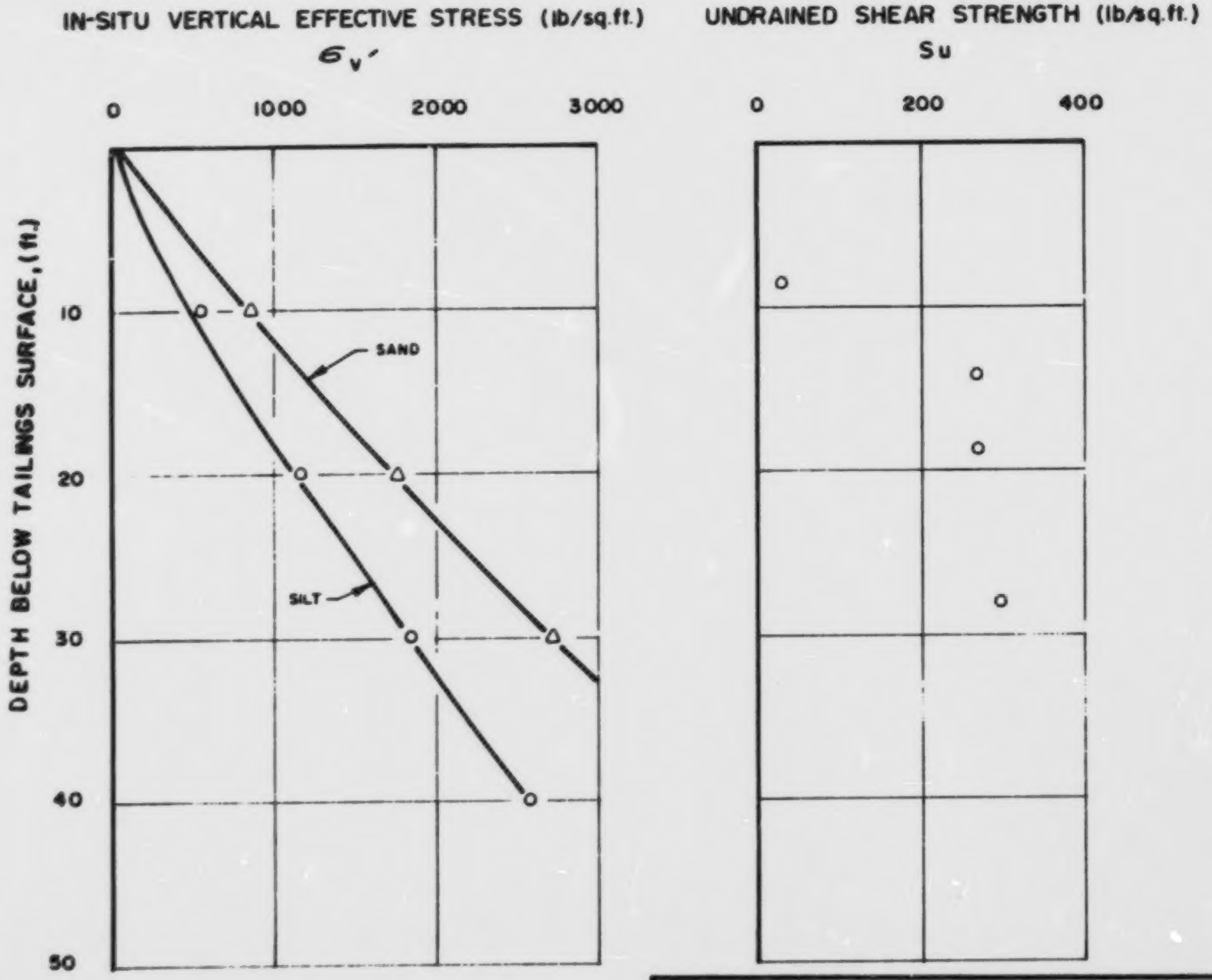
Chkd

IN-SITU PROPERTIES OF
TAILINGS DEPOSITED NEAR SPIGOT
(ELLIOT LAKE)

FIGURE 6



Date JULY 7, 1983
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Golder Associates

Drawn G.P.
Chkd

IN-SITU PROPERTIES OF
TAILINGS DEPOSITED NEAR SPIGOT
(ELLIOT LAKE)

FIGURE 6
(cont.)

February 21, 1984 Our ref: 821-1105-7

Ontario Research Foundation
Sheridan Park Research Community
2395 Speakman Drive
MISSISSAUGA, Ontario
L5K 1B3

ATTENTION: Dr. V. I. Lakshmanan

RE: GEOTECHNICAL LABORATORY TESTING
YOUR PURCHASE ORDER NO. 28846

Dear Sirs:

This letter reports the results of permeability tests which have been carried out on samples delivered to our laboratory on January 26, 1984.

The samples were received in plastic tubes which were identified by writing on the sample container. The tube samples were in a moist condition when received.

The test results are summarized on the attached Tables 1 to 4, inclusive.

We trust that this information is sufficient for your immediate purposes. If you have any questions regarding these results, please call us.

Yours truly,

GOLDER ASSOCIATES

F. A. Rydgren

FAR/jm

Enc. Tables 1 to 4
Tubes
Samples

TABLE 1

SUMMARY OF CONSTANT HEAD PERMEABILITY TEST RESULTS

GRID NO. B 1.5

TEST NO.	1	2	3	4	5	6
SAMPLE DEPTH* cm	0-9.9	9.9-14.9	14.9-18.7	18.7-23.8	23.8-27.6	27.6-31.4
WATER CONTENT, Initial %	53.2	60.9	71.4	77.6	49.9	53.9
WATER CONTENT, Final %	53.7	58.9	66.3	74.9	46.9	50.3
DRY DENSITY Mg/m^3	1.068	0.988	0.925	0.865	1.129	1.082
SAMPLE VOLUME cm^3	203.3	100.6	80.5	90.3	83.2	66.7
DRY WEIGHT g	217.2	99.3	74.4	78.1	94.0	72.2
SPECIFIC GRAVITY**	2.66	2.66	2.66	2.66	2.66	2.66
VOLUME SOLIDS cm^3	81.65	37.33	27.97	29.36	35.34	27.14
VOID RATIO e	1.490	1.694	1.877	2.074	1.355	1.459
POROSITY n	0.598	0.629	0.652	0.675	0.575	0.593
HEAD PRESSURE cm	77.3	74.5	70.3	74.5	74.5	70.8
HYDRAULIC GRADIENT I	7.8	15.3	18.0	17.0	18.5	20.6
COEFFICIENT OF PERMEABILITY, k cm/s	1.1x10^{-5}	3.4x10^{-6}	8.2x10^{-6}	4.9x10^{-6}	6.7x10^{-6}	8.4x10^{-6}

*Depth measured from top of sample

**Specific gravity assumed

TESTS CARRIED OUT USING THE MERCURY/WATER TRIAXIAL CONSTANT HEAD APPARATUS.

February 21, 1984

TABLE 2

SUMMARY OF CONSTANT HEAD PERMEABILITY TEST RESULTS

GRID NO. B 8.5

TEST NO.	1	2	3	4	5	6
SAMPLE DEPTH* cm	7.6-11.4	11.4-15.2	16.5-20.3	20.3-24.1	24.1-27.9	27.9-33.0
WATER CONTENT, Initial %	89.2	60.9	62.0	88.9	83.2	63.2
WATER CONTENT, Final %	85.2	58.6	60.6	87.9	78.1	58.1
DRY DENSITY Mg/m^3	0.761	0.981	0.973	0.750	0.807	0.953

SAMPLE VOLUME cm^3	79.3	83.9	86.7	68.3	84.3	118.3
DRY WEIGHT g	60.3	82.3	84.3	51.2	68.0	112.9
SPECIFIC GRAVITY**	2.66	2.66	2.66	2.66	2.66	2.66
VOLUME SOLIDS cm^3	22.67	30.94	31.69	19.25	26.15	42.44
VOID RATIO e	2.496	1.710	1.734	2.548	2.222	1.787
POROSITY n	0.714	0.631	0.634	0.718	0.690	0.641

HEAD PRESSURE cm	69.6	78.7	75.9	77.3	54.1	178.6
HYDRAULIC GRADIENT I	17.9	19.4	18.1	23.4	13.3	31.1
COEFFICIENT OF PERMEABILITY, k cm/s	2.6×10^{-6}	6.3×10^{-6}	3.2×10^{-6}	5.1×10^{-5}	4.7×10^{-6}	6.2×10^{-6}

Top 7.6 cm was not tested due to vertical splitting of sample.

*Depth measured from top of sample

**Specific gravity assumed

TESTS CARRIED OUT USING THE MERCURY/WATER TRIAXIAL CONSTANT HEAD APPARATUS.

TABLE 3

SUMMARY OF CONSTANT HEAD PERMEABILITY TEST RESULTS

GRID NO. H 1.5

TEST NO.	1	2	3	4	5	6
SAMPLE DEPTH* cm	5.1-10.2	10.2-15.2	15.2-20.3	20.3-25.4	25.4-30.5	30.5-35.6
WATER CONTENT, Initial %	125.1	146.9	148.8	160.4	153.1	146.0
WATER CONTENT, Final %	120.5	139.1	138.2	146.3	141.9	140.6
DRY DENSITY Mg/m^3	0.568	0.793	0.547	0.520	0.534	0.546
SAMPLE VOLUME cm^3	99.4	99.6	98.6	98.1	113.2	119.9
DRY WEIGHT g	56.5	53.5	53.9	51.0	60.4	65.5
SPECIFIC GRAVITY**	2.66	2.66	2.66	2.66	2.66	2.66
VOLUME SOLIDS cm^3	21.73	20.58	20.73	19.62	23.23	25.19
VOID RATIO e	3.576	3.842	3.757	4.001	3.871	3.758
POROSITY n	0.782	0.793	0.790	0.800	0.795	0.790
HEAD PRESSURE cm	51.3	59.8	54.1	73.1	53.4	61.2
HYDRAULIC GRADIENT I	10.6	12.4	11.3	15.4	9.7	10.5
COEFFICIENT OF PERMEABILITY, k cm/s	5.5×10^{-6}	7.2×10^{-6}	7.1×10^{-6}	4.7×10^{-6}	1.1×10^{-5}	3.0×10^{-6}

Top 5.1 cm was not tested due to vertical splitting of sample.

*Depth measured from top of sample

**Specific gravity assumed

TESTS CARRIED OUT USING THE MERCURY/WATER TRIAXIAL CONSTANT HEAD APPARATUS.

TABLE 4

SUMMARY OF CONSTANT HEAD PERMEABILITY TEST RESULTS

GRID NO. **H 8.5**

TEST NO.	1	2	3	4	5	6
SAMPLE DEPTH* cm	5.1-8.9	8.9-12.7	12.7-17.8	17.8-22.9	22.9-28.6	28.6-35.6
WATER CONTENT, Initial %	94.0	109.3	133.5	143.8	124.8	122.6
WATER CONTENT, Final %	96.3	107.5	127.6	137.3	116.9	115.8
DRY DENSITY Mg/m^3	0.747	0.649	0.572	0.526	0.604	0.619

SAMPLE VOLUME cm^3	78.5	77.9	94.9	108.2	118.7	133.8
DRY WEIGHT g	58.7	50.6	54.3	56.9	71.7	82.8
SPECIFIC GRAVITY**	2.66	2.66	2.66	2.66	2.66	2.66
VOLUME SOLIDS cm^3	22.07	19.02	20.41	21.39	26.95	31.13
VOID RATIO e	2.559	3.097	3.649	4.059	3.404	3.298
POROSITY n	0.719	0.756	0.785	0.802	0.773	0.767

HEAD PRESSURE cm	66.8	57.6	81.5	55.5	59.8	85.8
HYDRAULIC GRADIENT I	16.7	15.1	17.7	10.8	10.5	13.2
COEFFICIENT OF PERMEABILITY, k cm/s	$1.8x10^{-5}$	$5.4x10^{-6}$	$2.5x10^{-6}$	$3.0x10^{-6}$	$5.8x10^{-6}$	$6.3x10^{-6}$

Top 5.1 cm was not tested due to vertical splitting of sample.

*Depth measured from top of sample

**Specific gravity assumed

TESTS CARRIED OUT USING THE MERCURY/WATER TRIAXIAL CONSTANT HEAD APPARATUS.

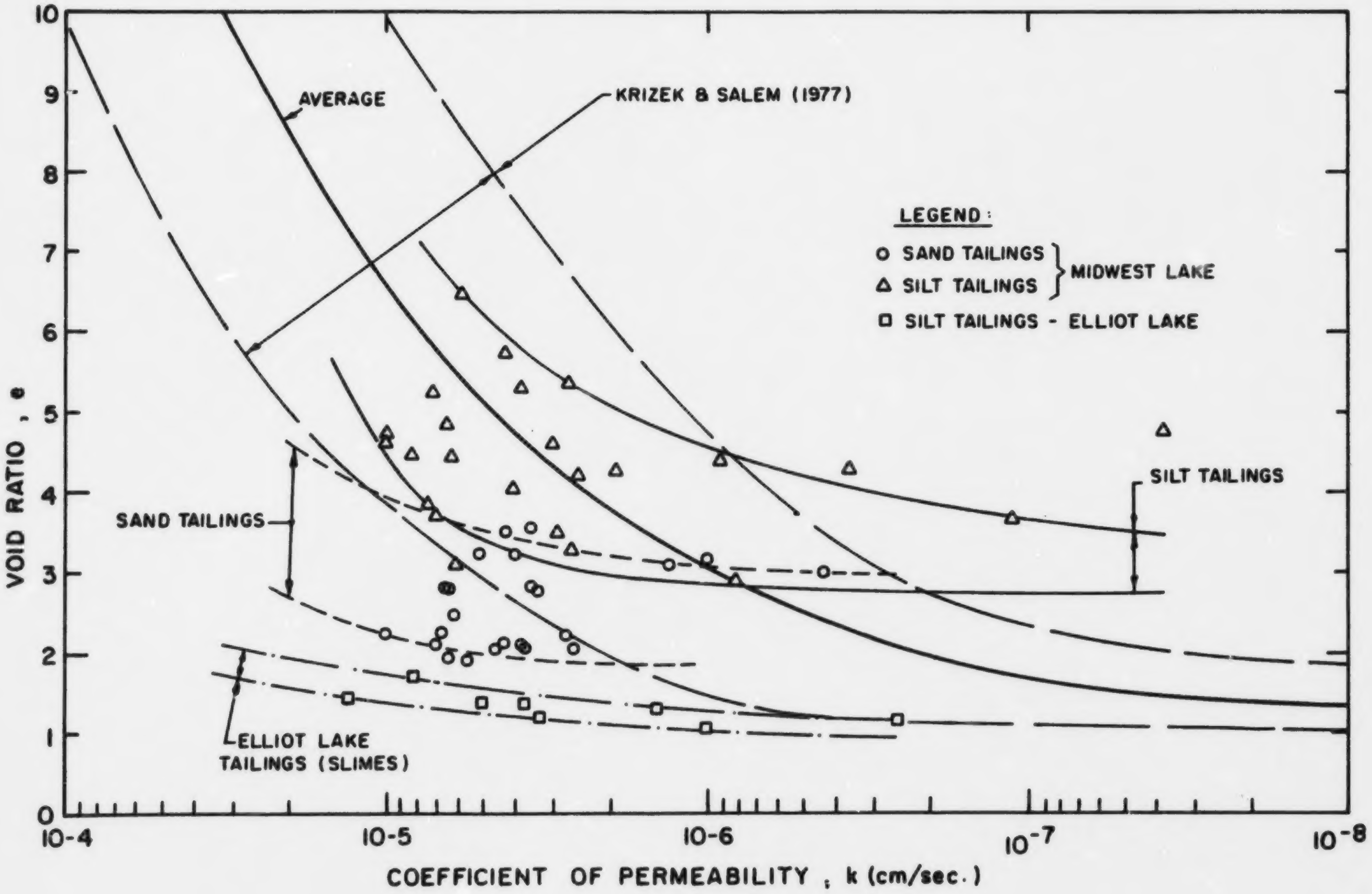

FIGURE 7. COEFFICIENT OF PERMEABILITY AS A FUNCTION OF VOID AREA.

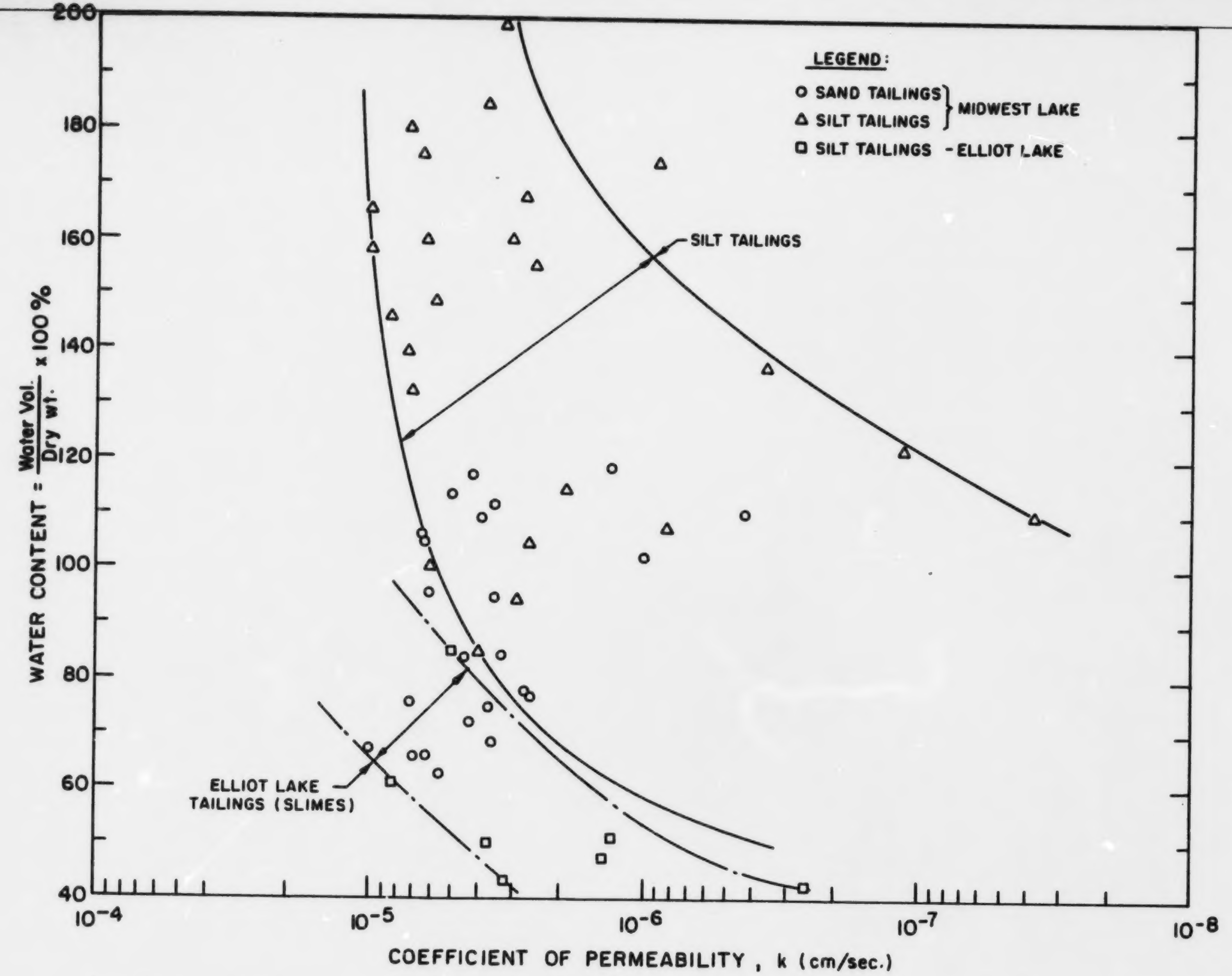

FIGURE 8 COEFFICIENT OF PERMEABILITY AS A FUNCTION OF WATER CONTENT.

Canada Centre for Mineral
and Energy Technology
Final Report

APPENDIX J

PARTICLE PORE CHARACTERISTIC VARIATION WITH DEPTH DATA PRODUCED BY THE ORF MATERIAL CHEMISTRY DIVISION

ONTARIO**RESEARCH**
FOUNDATION

SHERIDAN PARK RESEARCH COMMUNITY
MISSISSAUGA, ONTARIO, CANADA L5K 1B3 • (416) 822 4111 • TELEX 06 982311

September 17, 1982

TO: Dr. V.I. Lakshmanan
Department of Engineering & Metallurgy

REPORT NUMBER	PTA 208-82-1
IDENTIFICATION	W.O. #6442
SPECIFICATIONS OF ORDER	Pore Size Distribution and Density Measurements of Seventeen Uranium Tailings Samples by Mercury Porosimetry

---

1. INTRODUCTION

One factor that contributes to the hazardous nature of uranium mine tailings is radioactivity. One of the radioactive products of uranium mine tailings is radon gas. The porosity and the exposed surface of the tailings solids will give a measure of the surface from which radon gas emanation can occur. The objective of this project was to measure and compare the porosity of different parts of a tailings pond deposited by a layering method.

Seventeen samples were submitted for analysis by mercury intrusion porosimetry. Nine of these had been sampled May 31, 1982; eight of the samples had been obtained June 9, 1982. On each collection date, four portions of the pond were sampled, these being

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labelled nine, ten, eleven and twelve. Core samples were procured from these locations; samples analyzed were, from the top, labelled #1 and from the bottom, labelled #6. In addition, one sample at a relative depth of two, at sampling position nine, was also submitted for analysis.

2. METHOD OF ANALYSIS

All of the samples were analyzed using a Micromeritics Autopore 9200 Mercury Intrusion Porosimeter. This instrument is a fully automated porosimeter which operates on the principle common to all mercury porosimeters, that when mercury is forced into a pore in a solid material, the pressure required to fill the pore completely is in inverse proportion to the size of the pore. This relationship is outlined in the equation:

$$D = -(1/P)4Q \cos \theta$$

where D is pore diameter, P the applied pressure, Q the surface tension, and θ the contact angle. The volume of mercury, V, penetrating the pores in measured directly as a function of applied pressure. This D-V information serves as a means of characterizing the pore structures.

In evaluating the samples submitted, two parameters were defined. First, the surface tension of mercury which varies with purity (triple distilled used) was arbitrarily given a value of 485 dynes/cm, as recommended by the manufacturer of the porosimeter. Second, on the same advice, the contact angle between the mercury and the solid material supplied was given a value of 130°, as no specific information regarding this parameter was supplied with the samples. It should be noted, however, that the contact angle of mercury does vary somewhat with the composition of the solid, thus, the actual contact angle may have been slightly different.

For each sample, intrusion to 60,000 psi and extrusion to atmospheric pressure were performed using an initial filling pressure of 0.5 psi.

3. RESULTS

The mercury intrusion porosimetry of the samples was measured, data being summarized in Tables I and II. The complete set of data is given in Appendix I. The data which are summarized in Tables I and II are: bulk density, skeletal density, percent porosity, average pore diameter, total pore area, and hysteresis. The bulk density of the powder relates to the bulk density of the samples as analyzed. Thus, it should be noted that this density does not necessarily indicate the true density of the material as packed in the pond, i.e. the actual bulk density of the pile may be different than the powdered sample analyzed. This relationship could not be determined as no sample cores (solid cores) of the material were submitted for analysis. The skeletal density is a measurement of the density of the actual solid material which comprises particles. The percent porosity is the volume percent of the material comprising the pores. The average pore diameter is the average size of the surface pores. The total pore area gives a measure of the surface area of the sample on which pores are found. The hysteresis, that is the volume difference at a given intrusion and extrusion pressure, gives a measure of the openness of the pores. The more open the pore structure, the lower the hysteresis. The amount of hysteresis was measured by finding the maximum horizontal distance between the intrusion and the extrusion curves.

General observations from the data are:

- tailings solids are not homogeneous
- all samples are porous, porosities range from 43% to 71%
- all samples have a large hysteresis - this is indicative of partially blocked pores

It is difficult to determine any specific trends with respect to the position of the samples in the pond, with two exceptions: position 11 appears to have a lower bulk density and higher porosity than the others; and samples at the top portion of the pond tend to have lower porosities than those from the bottom. This, however, cannot be conclusively stated. Because the porosity of the solids is high, potential for release of the radon gas to the environment is high (because of high exposed surface). However, the morphology of the pores, that is, the fact that they are blocked and probably convoluted, means that there is a possibility that the radon gas will undergo radioactive decay prior to diffusing out of the pore.

An additional consideration is:

- the influence that the consolidation of the particles in the pile will have on the overall pile porosity.

If the particles are well consolidated and densely packed when the radon gas diffuses through the pores to the surface of the material, there is potential for further obstruction of the gaseous molecule by other particles. The amount of consolidation can only be measured by using bulk tailings pond samples.

Lydia M. Luckevich
Associate Research Scientist
Department of Materials Chemistry

Greg Hildebrand

Greg Hildebrand
Technologist I
Department of Materials Chemistry

/gb

TABLE I

POROSIMETRY DATA FOR TAILINGS POND POWDER SAMPLES: May 31, 1982 Samples

	T-9-1	T-9-2	T-9-6	T-10-1	T-10-6	T-11-1	T-11-6	T-12-1	T-12-6
Bulk Density (g/cc)	1.2890	0.8435	0.6931	0.8529	0.7996	0.4444	0.5413	0.5903	0.7482
Skeletal Density (g/cc)	2.3494	2.1507	1.9141	1.6635	1.8649	1.1997	1.8345	1.2619	1.7756
% Porosity	45%	61%	64%	49%	57%	63%	71%	53%	58%
Average Pore Diameter (μm)	0.2271	1.6656	2.3534	0.2948	1.6676	1.8665	1.6802	1.1613	1.6803
Total Pore Area m^2/g	6.1662	1.7304	1.5644	7.7514	1.7136	3.0360	3.1001	3.1060	1.8409
Hysteresis (cm)	8.3	7.4	7.2	8.2	7.5	7.3	7.8	8.2	7.3

TABLE II

POROSIMETRY DATA FOR TAILINGS POND POWDER SAMPLES: June 9, 1982 Samples

	T-9C-1	T-9C-6	T-10C-1	T-10C-6	T-11C-1	T-11C-6	T-12C-1	T-12C-6
Bulk Density (g/cc)	1.0543	0.8937	0.6929	0.7977	0.4412	0.4534	0.5382	0.4517
Skeletal Density (g/cc)	1.8562	1.6183	1.3924	1.8219	1.2040	1.4497	1.3858	1.4324
% Porosity	43%	45%	50%	56%	63%	69%	61%	68%
Average Pore Diameter (µm)	1.8426	0.3598	1.2448	1.5774	1.6172	0.2918	1.6134	1.9464
Total Pore Area (m^2/g)	0.8895	5.5691	2.3296	1.7869	3.5516	20.7833	2.8176	3.1153
Hysteresis (cm)	7.0	8.2	8.0	7.6	7.3	7.8	7.4	10.3

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Environment

ambient air quality assessment, environmental impact assessments, long-range transport of atmospheric pollutants, precipitation chemistry, particulate characterization studies, emission inventories, source sampling, odour emission and control, asbestos measurement and control, occupational health and safety studies, diesel emission control technology, air pollution control, pesticide residues, trace metal analysis, trace organic analysis, radionuclide analysis, mutagenic testing, noise and vibration analysis, radiation measurements, particulate identification and measurement, water surveys, water purification, industrial and municipal wastewater treatment, membrane separation techniques, wet oxidation, solid waste treatment and recovery, hazardous waste treatment and disposal, indoor air quality assessments, priority pollutant analysis, landfill technology, . . .

Materials

building materials, plastics, composites, metals, glass and ceramics, wood and wood composites, biomaterials, adhesives and printing inks, fibres, yarns, fabrics and geotextiles, leather, organic and inorganic chemicals, specification development, quality assurance, mechanical, chemical and thermal properties, test method development, failure analysis, fire and flammability, glass-metal seals, metal and alloy powders, metallography, materials characterization, materials characterization by optical and electron microscopy and X-ray microanalysis, photovoltaic materials, materials corrosion resource centre, corrosion properties and control, bacterial corrosion, coatings and sealants, rubber technology, X-ray analysis, cement and concrete, soils and aggregates, gypsum, body armour testing, footwear, paper-making materials, roofing and waterproofing, waste material stabilization and solidification, . . .

Products & Processes

clothing, footwear and industrial textile products, knitting technology, thin and thick film systems, microelectronics development, fibre optics, instrumentation, bioengineering, ultrasonic and fluid shear devices, microwave drying, transportation and equipment testing, mathematical stress and vibration analysis, product, equipment and machinery design & development, fuel emulsification, organic analysis and characterization, chemistry of foodstuffs, pulp and paper processes, ceramics processing, metallurgical process development, powder metal technology, packaging applications, technical and economic evaluations, industrial engineering applications, process control, enzyme analysis, electrical testing, radioactive surveys, industrial microbiology, biotechnology, technical and management skills development seminars, paper products, absorbent consumer products, detergent and cosmetic formulation, metal chemical analysis, flash hydropyrolysis of coal, electroplating, . . .

Resources

mineral processing, hydro and pyrometallurgical processing of ferrous and non-ferrous ores, coal evaluation, coal ash utilization and product development, asbestos processing and applications, non-metallic minerals/industrial minerals processing and utilization, uranium processing, forest utilization, utilization of forest and agricultural wastes, utilization of industrial, mining and domestic wastes, energy and chemicals from biomass, in-plant waste reduction, mineralogical services, mining and metallurgical waste disposal, . . .

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APPENDIX K

PARTICLE SIZE DISTRIBUTION OF VARIOUS CORES WITH DEPTH

ORI

CORE STRUCTURE - GRADING ANALYSIS
AT VARIOUS GRID POSITIONS

		CORE: B-1 April 1, 1982			CORE: B-3 May 31, 1982		
CORE DEPTH - Cm		0 - 12	12 - 24	24 - 36	0 - 11	11 - 22	22 - 33
MESH CYCLONE	MICRON SIZE	CUMULATIVE WEIGHT % PASSING SIZE					
35	420	99.6	99.9	99.6	99.5	99.5	99.4
48	297	93.9	94.7	96.0	92.9	94.2	93.4
65	210	86.1	87.2	83.6	83.5	79.4	86.1
100	149	57.7	59.6	67.1	49.0	63.8	59.6
150	105	46.8	49.4	56.9	37.6	54.9	49.7
200	74	38.4	42.3	49.7	30.6	48.8	43.0
CYCLONE 1	48	34.2	39.1	47.0	27.2	45.4	39.6
2	36	31.5	36.8	45.3	25.2	43.4	37.7
3	25	29.5	35.0	43.9	23.7	41.9	36.3
4	17	28.3	33.8	42.8	22.8	40.5	35.2
5	12	27.7	33.1	42.2	22.1	39.8	34.8
SPECIFIC GRAVITY		-	-	-	-	-	2.61
MOISTURE %		40.5	45.8	51.1	45.9	49.0	35.0

CORE STRUCTURE - GRADING ANALYSIS
AT VARIOUS GRID POSITIONS

		CORE: B-9 April 1, 1982			CORE: B-7 · May 31, 1982		
CORE DEPTH - Cm		0 - 12	12 - 24	24 - 36	0 - 8	8 - 16	16 - 24
MESH CYCLONE	MICRON SIZE	CUMULATIVE WEIGHT % PASSING SIZE					
35	420	99.7	99.7	99.9	99.4	99.3	99.3
48	297	90.4	93.6	92.3	93.1	92.1	90.6
65	210	79.7	80.1	83.5	78.5	84.4	81.5
100	149	52.1	67.0	57.3	64.2	59.5	50.4
150	105	42.7	59.7	48.1	56.1	50.2	45.5
200	74	35.8	53.2	41.1	50.6	43.8	39.8
CYCLONE 1	48	33.4	50.7	38.6	47.2	40.6	37.4
2	36	31.8	48.7	36.9	45.2	38.4	35.8
3	25	30.6	46.9	35.5	43.5	36.6	34.5
4	17	29.8	45.5	34.7	42.5	35.0	33.7
5	12	29.2	44.8	34.1	41.7	34.3	33.1
SPECIFIC GRAVITY		-	-	-	2.60	2.62	2.60
MOISTURE %		46.9	51.3	46.9	47.0	43.8	49.6

CORE STRUCTURE - GRADING ANALYSIS
AT VARIOUS GRID POSITIONS

		CORE: F-1 April 1, 1982			CORE: H-1 May31,1982		
CORE DEPTH - Cm		0 - 5	5 - 10	10 - 15	0 - 8	8 - 16	16 - 23
MESH CYCLONE	MICRON SIZE	CUMULATIVE WEIGHT % PASSING SIZE					
35	420	99.7	99.8	99.5	99.8	96.8	99.8
48	297	93.6	98.6	97.0	97.5	85.6	99.3
65	210	77.8	94.2	85.2	90.0	78.5	98.5
100	149	65.4	87.5	72.5	80.5	72.3	93.8
150	105	58.2	81.5	64.9	73.8	66.8	89.3
200	74	52.0	74.6	59.1	67.6	60.3	83.8
CYCLONE 1	48	48.1	72.1	56.5	64.2	56.4	80.7
2	36	45.2	69.8	54.7	61.5	52.7	77.6
3	25	42.7	68.0	52.9	59.0	49.1	74.6
4	17	40.6	67.2	51.2	56.6	46.4	71.9
5	12	39.6	66.3	50.5	55.5	44.8	70.3
SPECIFIC GRAVITY		-	-	-	2.60	2.58	2.59
MOISTURE %		50.6	61.0	53.7	65.2	51.4	65.4

CORE STRUCTURE - GRADING ANALYSIS AT VARIOUS GRID POSITIONS

		CORE: F-9 April 1, 1982			CORE: H-9 May 31, 1982		
CORE DEPTH - Cm		0 - 5	5 - 10	10 - 15	0 - 7	7 - 14	14 - 23
MESH CYCLONE	MICRON SIZE	CUMULATIVE WEIGHT % PASSING SIZE					
35	420	99.9	99.9	99.9	99.6	99.9	99.7
48	297	97.8	95.7	95.9	95.0	98.8	97.5
65	210	94.4	84.3	91.6	90.6	95.4	95.2
100	149	81.6	72.3	73.1	76.2	89.6	86.7
150	105	74.6	64.4	64.4	69.4	83.8	81.4
200	74	67.1	58.0	56.5	63.2	77.4	75.3
CYCLONE 1	48	64.0	55.0	52.5	60.1	73.5	72.1
2	36	61.4	52.7	49.7	57.7	70.1	67.8
3	25	59.4	50.5	48.0	55.5	67.0	62.7
4	17	58.6	48.6	47.2	53.9	64.3	59.5
5	12	57.7	47.7	46.3	52.8	62.9	57.9
SPECIFIC GRAVITY		-	-	-	2.62	2.62	2.63
MOISTURE %		62.7	51.8	51.4	56.3	55.5	59.0

CORE STRUCTURE - SIZE ANALYSIS

AT VARIOUS GRID POSITIONS

Core Grid Position		C - 2.25 (Core taken January 5, 1983)							
Core Depth Position		1	2	3	4	5	6	7	8
Core Depth - (cm)		0-6.35	6.35-12.7	12.7-19.1	19.1-25.4	25.4-31.8	31.8-38.1	38.1-47.0	47.0-55.9
Mesh or Cyclone	Micron Size	Cumulative Weight % Passing Size							
35	420	99.3	99.2	99.3	99.0	99.3	99.5	96.5	99.1
48	297	90.3	89.1	93.4	95.8	93.5	95.7	92.3	93.6
65	210	78.5	79.6	86.8	92.5	87.5	87.0	85.5	87.7
100	149	54.9	59.7	61.7	88.8	73.4	68.6	65.8	66.3
150	105	44.1	50.4	51.2	79.7	64.5	58.4	54.0	52.0
200	74	33.1	45.0	45.5	73.5	58.6	52.7	46.0	42.4
Cyclone 1	48	30.7	42.0	43.0	71.1	56.0	50.5	43.6	40.3
2	36	28.2	39.8	40.7	68.4	54.1	48.4	40.9	38.0
3	25	26.2	37.8	38.8	66.2	52.7	46.6	38.7	36.1
4	17	24.7	36.3	37.4	64.4	51.6	45.3	37.1	34.9
5	12	24.0	35.5	36.7	63.3	51.1	44.5	36.3	34.5
Moisture (%)		33.7	48.2	44.7	55.9	54.2	49.1	39.8	49.7
Sample Ident A#		4493	4494	4495	4496	4497	4498	4499	4500

CORE STRUCTURE - SIZE ANALYSIS
AT VARIOUS GRID POSITIONS

Core Grid Position		C - 7.25 (Core taken January 5, 1983)							
Core Depth Position		1	2	3	4	5	6	7	8
Core Depth - (cm)		0-6.35	6.35-12.7	12.7-19.1	19.1-25.4	25.4-31.8	31.8-38.1	38.1-44.5	44.5-50.8
Mesh or Cyclone	Micron Size	Cumulative Weight % Passing Size							
35	420	98.4	99.2	98.2	97.6	94.6	94.7	95.1	95.3
48	297	91.8	92.0	91.6	91.0	87.3	88.4	88.8	90.7
65	210	83.5	87.0	86.4	81.0	70.1	74.5	85.1	87.7
100	149	64.6	83.0	80.6	62.9	54.6	60.1	64.7	72.8
150	105	55.9	74.1	72.4	53.4	44.0	49.9	53.8	63.6
200	74	50.9	68.4	67.2	47.9	37.1	42.7	43.8	57.0
Cyclone 1	48	48.6	66.3	65.1	45.7	35.2	40.3	41.1	54.1
2	36	46.3	64.2	62.9	43.3	32.9	37.5	38.2	50.7
3	25	44.4	62.3	60.9	41.3	31.1	35.2	35.5	47.7
4	17	42.9	60.8	59.3	39.7	29.6	33.4	33.3	45.4
5	12	42.1	60.0	58.3	38.9	28.6	32.5	32.1	44.1
Moisture (%)		51.5	48.6	48.1	45.2	36.2	45.2	55.9	49.3
Sample Ident A#		4501	4502	4503	4504	4505	4506	4507	4508

CORE STRUCTURE - SIZE ANALYSIS
AT VARIOUS GRID POSITIONS

Core Grid Position		G - 2.25 (Core taken January 5, 1983)					
Core Depth Position		1	2	3	4	5	6
Core Depth - (cm)		0-5.7	5.7-11.4	11.4-17.1	17.1-22.9	22.9-28.6	28.6-34.3
Mesh or Cyclone	Micron Size	Cumulative Weight % Passing Size					
35	420	94.8	96.8	97.5	99.2	93.2	98.4
48	297	88.9	92.3	94.8	95.9	90.8	90.5
65	210	76.1	89.1	92.0	90.3	86.9	84.9
100	149	63.3	80.8	80.1	84.3	81.7	75.4
150	105	55.2	75.1	73.2	79.6	76.4	67.2
200	74	48.6	70.6	67.7	74.9	72.3	58.7
Cyclone 1	48	45.8	68.6	65.5	73.2	70.7	57.3
2	36	42.3	65.9	62.8	70.9	68.5	55.4
3	25	39.1	63.3	60.3	68.5	66.3	53.1
4	17	36.6	60.9	58.1	66.2	64.1	51.1
5	12	35.2	59.5	56.8	64.7	62.9	49.9
Moisture (%)		53.2	60.2	56.6	61.9	60.3	55.7
Sample Ident A#		4509	4510	4511	4512	4513	4514

CORE STRUCTURE - SIZE ANALYSIS
AT VARIOUS GRID POSITIONS

Core Grid Position		G - 7.25 (Core taken January 5, 1983)					
Core Depth Position		1	2	3	4	5	6
Core Depth - (cm)		0-5.7	5.7-11.4	11.4-17.1	17.1-22.9	22.9-28.6	28.6-34.3
Mesh or Cyclone	Micron Size	Cumulative Weight % Passing Size					
35	420	98.8	98.3	98.9	98.9	98.0	96.7
48	297	96.8	95.5	94.6	96.6	92.2	94.1
65	210	90.1	89.3	87.4	93.2	87.9	90.2
100	149	82.1	81.5	80.2	86.2	81.6	85.0
150	105	74.2	73.9	70.8	81.4	75.8	79.8
200	74	68.3	67.4	64.6	78.0	70.9	75.6
Cyclone 1	48	65.5	65.1	62.0	76.5	69.7	74.2
2	36	62.2	61.9	58.4	74.3	67.2	72.1
3	25	59.1	58.7	55.3	72.0	64.3	69.7
4	17	56.5	56.0	53.2	69.7	61.5	67.3
5	12	55.0	54.4	52.2	68.2	59.9	65.6
Moisture (%)		61.3	55.9	47.7	58.0	61.5	65.6
Sample Ident A#		4515	4516	4517	4518	4519	4520

CORE STRUCTURE - SIZE ANALYSIS
AT VARIOUS GRID POSITIONS
CORES TAKEN APRIL 5/83

Core Grid Position		B - C - 2.5							
Core Depth Position		1	2	3	4	5	6	7	8
Core Depth - (cm)		0-7.6	7.6-14	14-20.4	20.4-26.8	26.8-33.2	33.2-39.6	39.6-46.0	46.0-52.4
Mesh or Cyclone	Micron Size	Cumulative Weight % Passing Size							
35	420	97.9	98.1	99.3	99.6	99.5	99.7	99.4	99.4
48	297	88.1	87.4	91.7	94.7	94.1	94.7	94.8	96.0
65	210	66.1	68.0	79.2	89.0	84.2	83.3	81.9	87.7
100	149	49.6	45.9	58.1	69.8	65.6	63.6	59.2	71.6
150	105	39.1	34.7	48.0	60.2	55.5	52.1	46.5	59.8
200	74	32.6	28.9	42.2	54.6	49.8	46.2	39.6	53.3
Cyclone 1	48	29.8	26.3	39.4	51.8	47.3	42.9	35.6	49.9
2	36	27.6	24.6	37.1	49.6	45.4	40.9	33.2	47.1
3	25	25.7	23.2	35.2	47.5	44.0	39.3	31.2	44.7
4	17	24.3	22.2	33.8	46.0	42.9	38.2	29.9	42.8
5	12	23.5	21.6	33.0	45.3	42.3	37.5	29.2	41.8
Moisture (%)		34.1	36.1	46.8	52.9	54.1	47.8	41.3	50.9
Sample Ident - A#		4711	4712	4713	4714	4715	4716	4717	4718

CORE STRUCTURE - SIZE ANALYSIS
AT VARIOUS GRID POSITIONS
CORES TAKEN APRIL 5/83

Core Grid Position		B - C - 7.5							
Core Depth Position		1	2	3	4	5	6	7	8
Core Depth - (cm)		0-7.0	7-13	13-19	19-25	25-31	31-37	37-43	43-49
Mesh or Cyclone	Micron Size	Cumulative Weight % Passing Size							
35	420	98.9	98.9	99.4	99.5	98.4	98.6	99.0	97.0
48	297	93.3	88.9	91.9	94.2	89.2	91.9	94.6	87.1
65	210	85.2	76.8	84.5	89.9	79.3	81.3	89.0	78.8
100	149	66.9	57.1	65.4	67.7	53.2	55.7	65.1	58.6
150	105	58.6	48.5	58.0	59.2	43.8	43.9	52.8	47.2
200	74	53.5	43.8	53.3	53.9	38.6	37.4	45.6	40.1
Cyclone 1	48	50.4	41.2	50.3	51.0	36.2	33.8	41.8	35.5
2	36	48.3	39.3	48.0	48.8	34.2	30.7	38.8	32.2
3	25	46.4	37.7	45.8	46.2	32.6	28.0	36.0	29.3
4	17	44.9	36.6	44.2	44.4	31.5	26.3	34.1	27.0
5	12	44.1	36.0	43.2	43.4	30.9	25.5	33.1	25.7
Moisture (%)		50.5	46.4	51.5	52.1	38.9	39.3	42.1	46.6
Sample Ident - A#		4719	4720	4721	4722	4723	4724	4725	4726

CORE STRUCTURE - SIZE ANALYSIS
AT VARIOUS GRID POSITIONS
CORES TAKEN APRIL 5/83

Core Grid Position		G - H - 2.5					
Core Depth Position		1	2	3	4	5	6
Core Depth - (cm)		0-4.5	4.5-9.6	9.6-14.7	14.7-19.8	19.8-24.9	24.9-30.0
Mesh or Cyclone	Micron Size		Cumulative Weight % Passing Size				
35	420	94.0	95.7	95.7	96.5	99.9	99.9
48	297	89.0	88.0	90.5	92.3	98.2	99.1
65	210	82.3	79.7	85.0	87.8	96.5	97.4
100	149	71.5	61.3	75.6	79.2	91.7	91.9
150	105	61.1	49.5	66.5	71.5	88.0	87.4
200	74	51.9	39.3	58.0	64.2	84.5	83.9
Cyclone 1	48	48.1	35.3	55.4	61.7	82.5	81.1
2	36	44.5	32.0	52.8	59.2	80.4	78.9
3	25	40.3	27.7	49.6	56.0	77.4	75.9
4	17	37.0	24.3	47.3	53.5	74.6	73.1
5	12	35.0	22.4	45.6	52.0	72.7	71.3
Moisture (%)		60.2	61.5	66.6	64.5	60.3	63.6
Sample Ident - A#		4727	4728	4729	4730	4731	4732

CORE STRUCTURE - SIZE ANALYSIS
AT VARIOUS GRID POSITIONS
CORES TAKEN APRIL 5/83

Core Grid Position		G - H - 7.5					
Core Depth Position		1	2	3	4	5	6
Core Depth - (cm)		0-4.9	4.9-10	10-15.1	15.1-20.2	20.2-25.3	25.3-30.4
Mesh or Cyclone	Micron Size	Cumulative Weight % Passing Size					
35	420	99.9	99.6	99.8	95.9	99.9	99.9
48	297	98.7	98.9	98.6	94.8	99.9	99.3
65	210	96.1	98.0	96.2	93.3	99.8	97.8
100	149	84.2	90.8	89.3	89.5	99.1	93.5
150	105	75.8	85.2	84.0	86.9	97.5	89.5
200	74	70.0	80.2	79.1	84.4	95.4	85.7
Cyclone 1	48	65.9	76.8	75.9	82.7	93.7	83.1
2	36	62.6	73.8	72.6	80.5	91.7	80.4
3	25	59.5	70.7	69.3	77.4	88.9	77.3
4	17	57.1	68.3	66.7	74.6	86.3	74.7
5	12	55.6	66.8	65.3	72.7	84.9	73.1
Moisture (%)		57.7	61.1	56.0	59.5	62.5	59.6
Sample Ident. - A#		4733	4734	4735	4736	4737	4738

Core Structure - Size Analysis
at Various Grid Positions
Cores Taken 26/7/83

Core Grid Position		C2							
Core Depth Position		1	2	3	4	5	6	7	8
Core Depth - (cm)		0-6	6-12	12-18	18-24	24-30	30-36	36-42	42-48
Mesh or Cyclone	Micron Size	Cumulative Weight % Passing Size							
35	420	98.1	97.9	98.8	98.8	98.4	99.0	99.2	97.7
48	297	79.9	76.6	86.2	88.1	90.8	93.4	91.7	95.8
64	210	51.0	54.8	72.4	72.8	76.7	83.9	76.3	84.5
100	149	35.0	40.7	60.6	61.0	62.4	65.6	56.3	70.6
150	105	26.2	33.1	53.1	52.2	51.5	51.6	44.5	59.2
200	74	21.0	27.1	46.2	45.1	43.1	41.4	35.7	51.0
Cyclone 1	48	18.6	24.0	42.2	40.9	38.3	37.0	31.9	46.5
2	36	17.1	21.9	39.2	38.1	35.5	33.6	29.6	43.8
3	25	16.0	20.0	36.7	35.8	33.4	31.2	27.5	41.3
4	17	15.2	18.7	34.9	34.2	32.0	29.8	25.9	39.6
5	12	14.8	17.9	33.9	33.3	31.3	29.2	25.0	38.8
Moisture (%)		27.1	34.5	36.9	41.8	45.7	40.3	46.0	51.5
Sample Ident. A#		4857	4858	4859	4860	4861	4862	4863	4864

Core Structure - Size Analysis
at Various Grid Positions
Cores Taken 26/7/33

Core Grid Position		C7							
Core Depth Position		1	2	3	4	5	6	7	8
Core Depth - (cm)		0-6	6-12	12-18	18-24	24-30	30-36	36-42	42-48
Mesh or Cyclone	Micron Size	Cumulative Weight % Passing Size							
35	420	99.1	99.1	99.5	99.1	99.6	99.2	99.7	99.8
48	297	92.5	87.7	93.8	91.2	91.6	90.7	93.7	97.2
64	210	80.7	65.4	80.8	74.5	76.2	79.7	83.6	90.6
100	149	67.3	48.8	67.5	59.7	61.6	66.2	69.2	82.1
150	105	58.8	38.7	57.8	49.9	50.4	56.6	58.9	73.6
200	74	52.5	32.6	51.3	43.9	42.6	48.4	49.8	66.0
Cyclone 1	48	50.3	30.1	48.0	41.1	39.0	45.1	46.0	62.1
2	36	48.8	27.5	45.4	39.1	36.5	42.6	43.2	58.9
3	25	47.4	25.3	43.0	37.1	34.1	40.1	40.5	55.8
4	17	46.3	23.6	41.1	35.6	44.7	38.3	38.4	53.5
5	12	45.6	22.5	40.0	34.9	31.6	37.3	37.1	52.2
Moisture (%)		47.9	48.2	50.9	47.4	46.1	45.2	56.5	48.4
Sample Ident. A#		4865	4866	4867	4868	4869	4870	4871	4872

Core Structure - Size Analysis
at Various Grid Positions
Cores Taken 26/7/83

Core Grid Position		G2							
Core Depth Position		1	2	3	4	5	6	7	8
Core Depth - (cm)		0-6	6-12	12-18	18-24	24-30	30-36	36-42	42-48
Mesh or Cyclone	Micron Size	Cumulative Weight % Passing Size							
35	420	99.2	99.9	99.9	100.0	100.0	99.9		
48	297	88.3	98.2	99.1	98.7	99.4	99.0		
64	210	71.8	92.8	95.6	94.4	97.2	96.6		
100	149	56.1	86.0	90.4	88.2	93.7	92.2		
150	105	45.9	79.2	85.2	83.2	90.1	88.3		
200	74	38.1	73.2	80.3	77.1	86.6	83.0		
Cyclone 1	48	34.5	69.5	77.3	74.9	85.1	79.8		
2	36	31.6	66.6	74.6	72.7	83.1	76.7		
3	25	28.9	63.5	71.7	70.2	80.9	73.2		
4	17	26.9	61.0	69.2	68.3	78.7	70.3		
5	12	25.8	59.4	67.7	67.2	77.3	68.5		
Moisture (%)		42.3	60.7	61.7	62.0	62.9	58.7		
Sample Ident. A#		4873	4874	4875	4876	4877	4878		

Core Structure - Size Analysis at Various Grid Positions Cores Taken 26/7/83

Core Grid Position		G7							
Core Depth Position		1	2	3	4	5	6	7	8
Core Depth - (cm)		0-6	6-12	12-18	18-24	24-30	30-36	36-42	42-48
Mesh or Cyclone	Micron Size	Cumulative Weight % Passing Size							
35	420	98.9	99.6	98.8	99.9	99.8	98.9		
48	297	95.1	96.0	90.6	99.3	98.8	97.7		
64	210	86.4	87.9	69.8	97.7	96.2	94.8		
100	149	74.9	77.2	47.8	95.4	92.3	89.4		
150	105	66.6	69.8	34.1	92.7	89.0	84.5		
200	74	58.7	63.3	27.1	89.9	84.5	78.3		
Cyclone 1	48	54.6	59.9	24.2	88.5	81.9	75.4		
2	36	51.6	57.4	22.2	86.7	78.6	72.2		
3	25	48.6	55.1	20.2	84.6	75.1	68.7		
4	17	46.2	53.8	18.9	82.4	72.7	65.8		
5	12	44.5	52.7	18.2	80.8	71.5	64.1		
Moisture (%)		60.6	49.3	51.3	63.4	57.1	55.0		
Sample Ident. A#		4879	4880	4881	4882	4883	4884		

Core Structure - Size Analysis
at Various Grid Positions
Cores Taken 26/7/83

Core Grid Position		Freezer Box							
Core Depth Position		1	2	3	4	5	6	7	8
Core Depth - (cm)		0-6	6-12	12-18	18-24	24-30	30-36	36-42	42-48
Mesh or Cyclone	Micron Size	Cumulative Weight % Passing Size							
35	420	98.4	99.2	99.1	97.7	99.7	99.4	99.8	90.7
48	297	90.9	93.7	94.6	96.7	95.7	97.0	99.1	89.6
64	210	75.7	80.7	85.4	88.2	88.9	89.9	95.4	87.9
100	149	61.9	68.3	73.6	79.2	80.0	79.7	88.5	84.3
150	105	51.7	59.6	65.6	71.6	72.8	69.6	80.9	80.4
200	74	44.1	53.4	58.9	65.2	66.7	61.2	73.8	76.2
Cyclone 1	48	39.9	N.A.	55.4	62.0	63.3	57.2	69.6	73.7
2	36	37.0	N.A.	53.0	59.5	60.6	54.0	66.5	71.8
3	25	34.3	N.A.	50.8	56.9	58.3	50.9	63.4	69.7
4	17	32.5	N.A.	49.1	54.9	56.6	48.6	61.0	67.8
5	12	31.3	N.A.	48.0	53.7	55.8	47.3	59.5	66.7
Moisture (%)		37.0	51.4	45.6	56.8	51.0	53.5	60.2	54.3
Sample Ident. A#		4889	4890	4891	4892	4893	4894	4895	4896

CORE STRUCTURE - SIZE ANALYSIS
AT VARIOUS GRID POSITIONS
CORES TAKEN JAN. 16, 1984

Core Grid Position: B-1.5

Core Depth Position:		1	2	3	4	5	6
*Core Segment Depth Based On:	Actual Core Length (cm)	0-5	5-10	10-15	15-20	20-25	25-30
	Observed Core Depth (cm)	0-9.7	9.7-19.4	19.4-29.1	29.1-38.8	38.8-48.5	48.5-58
Tyler Mesh or Cyclone #	Micron Size	CUMULATIVE WEIGHT % PASSING SIZE					
35	420	98.2	99.2	97.6	99.4	99.5	98.8
48	297	93.0	91.1	88.5	92.2	94.3	94.6
65	210	73.0	68.8	67.5	73.0	79.0	79.8
100	149	43.5	44.3	46.9	51.4	55.6	57.1
150	105	26.1	31.9	32.4	36.1	38.0	36.6
200	74	15.9	25.0	24.2	27.2	24.5	24.4
Cyclone 1	48	12.5	21.7	21.4	23.3	19.5	19.8
2	36	9.7	19.1	18.5	20.3	15.0	16.3
3	25	7.7	16.8	16.2	17.7	12.1	13.9
4	17	6.4	14.9	14.4	15.6	10.4	12.4
5	12	5.7	13.4	13.4	14.6	9.6	11.6
Moisture (%)		23.4	33.7	35.2	35.3	29.1	37.5
Sample Ident. A#		5246	5247	5248	5249	5250	5251

* Difference due to compression of core during extraction.

CORE STRUCTURE - SIZE ANALYSIS
AT VARIOUS GRID POSITIONS
CORES TAKEN JAN. 16, 1984

Core Grid Position: B-8.5

Core Depth Position:		1	2	3	4	5	6
*Core Segment Depth Based On:	Actual Core Length (cm)	0-6.5	6.5-13	13-19.5	19.5-26	26-32.5	32.5-39
	Observed Core Depth (cm)	0-9.7	9.7-19.4	19.4-29.1	29.1-38.8	38.8-48.5	48.5-58
Tyler Mesh or Cyclone #	Micron Size	CUMULATIVE WEIGHT % PASSING SIZE					
35	420	96.2	59.3	98.7	98.9	99.1	98.8
48	297	86.0	54.8	87.2	88.2	91.5	91.0
65	210	65.8	51.4	63.2	67.5	71.8	73.0
100	149	47.4	48.8	45.0	48.4	50.1	48.0
150	105	34.6	47.0	34.6	38.6	35.8	32.6
200	74	26.9	44.9	28.5	31.8	28.3	22.3
Cyclone 1	48	24.3	42.4	26.2	29.6	25.3	19.1
2	36	21.5	38.9	23.9	27.0	22.4	15.8
3	25	19.1	35.6	21.8	24.7	19.6	13.3
4	17	17.1	32.5	20.1	22.8	17.3	11.6
5	12	15.8	30.4	19.1	21.7	16.0	10.7
Moisture (%)		39.9	46.5	40.4	52.9	38.6	32.6
Sample Ident. A#		5252	5253	5254	5255	5256	5257

* Difference due to compression of core during extraction.

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CORE STRUCTURE - SIZE ANALYSIS
AT VARIOUS GRID POSITIONS
CORES TAKEN JAN. 16, 1984

Core Grid Position: H-1.5

Core Depth Position:		1	2	3	4	5	6
*Core Segment Depth Based On:	Actual Core Length (cm)	0-6.5	6.5-13	13-19.5	19.5-26	26-32.5	32.5-39
	Observed Core Depth (cm)	0-6.8	6.8-13.6	13.6-20.4	20.4-27.2	27.2-34.5	34-40.8
Tyler Mesh or Cyclone #	Micron Size	CUMULATIVE WEIGHT % PASSING SIZE					
35	420	97.3	99.7	100.0	99.9	99.9	99.4
48	297	95.7	97.8	99.4	99.8	98.4	91.6
65	210	92.7	92.9	96.6	99.1	94.2	75.2
100	149	88.5	85.8	91.2	97.4	89.1	57.7
150	105	82.8	79.0	85.1	94.6	83.8	47.5
200	74	76.2	71.2	78.5	90.3	77.5	40.3
Cyclone 1	48	73.6	67.6	75.2	87.1	74.2	37.9
2	36	68.6	61.6	70.5	82.7	69.8	35.9
3	25	61.8	55.4	65.3	77.3	64.7	33.8
4	17	59.3	50.5	60.4	71.8	59.4	31.6
5	12	54.8	47.5	57.5	67.7	55.6	30.0
Moisture (%)		55.3	59.6	60.3	60.8	60.7	47.5
Sample Ident. A#		5258	5259	5260	5261	5262	5263

* Difference due to compression of core during extraction.

CORE STRUCTURE - SIZE ANALYSIS
AT VARIOUS GRID POSITIONS
CORES TAKEN JAN. 16, 1984

Core Grid Position: H-8.5

Core Depth Position:		1	2	3	4	5	6
*Core Segment Depth Based On:	Actual Core Length (cm)	0-6	6-12	12-18	18-24	24-30	30-36
	Observed Core Depth (cm)	0-10.2	10.2-20.4	20.4-30.6	30.6-40.8	40.8-51.	51-61.2
Tyler Mesh or Cyclone #	Micron Size	CUMULATIVE WEIGHT % PASSING SIZE					
35	420	94.7	99.7	99.8	99.9	99.5	60.5
48	297	91.6	97.5	98.5	99.4	97.8	55.4
65	210	83.8	89.6	94.2	96.5	93.5	50.1
100	149	72.7	79.7	87.9	90.6	86.6	44.6
150	105	63.1	69.9	81.7	85.1	80.2	39.8
200	74	53.7	61.4	75.1	79.1	73.1	36.1
Cyclone 1	48	49.6	57.3	72.2	75.9	70.0	35.2
2	36	45.2	52.2	68.6	72.0	65.6	33.2
3	25	41.0	47.0	64.6	67.8	60.5	30.8
4	17	37.4	42.6	60.3	64.0	55.9	28.4
5	12	35.3	40.0	57.5	61.5	52.9	26.9
Moisture (%)		49.2	51.7	57.0	59.2	56.5	43.2
Sample Ident. A#		5264	5265	5266	5267	5268	5269

* Difference due to compression of core during extraction.

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CORE STRUCTURE - SIZE ANALYSIS
AT VARIOUS GRID POSITIONS
CORES TAKEN JAN. 16, 1984

Core Grid Position: B-5

Core Depth Position:		1	2	3	4	5	6
*Core Segment Depth Based On:	Actual Core Length (cm)	0-5.5	5.5-11	11-16.5	16.5-22	22-27.5	27.5-33
	Observed Core Depth (cm)	0-10.2	10.2-20.4	20.4-30.6	30.6-40.8	40.8-51.	51-61.2
Tyler Mesh or Cyclone #	Micron Size	CUMULATIVE WEIGHT % PASSING SIZE					
35	420	98.5	99.3	99.2	99.7	99.5	99.1
48	297	89.2	88.0	87.4	94.2	94.2	94.0
65	210	65.2	62.7	65.5	77.8	67.3	81.6
100	149	43.6	41.6	45.3	56.5	54.5	61.4
150	105	30.8	31.3	34.7	39.2	39.3	47.1
200	74	23.8	23.4	27.7	28.4	30.7	35.8
Cyclone 1	48	21.1	20.4	24.9	23.9	27.3	31.9
2	36	18.5	17.4	22.3	20.2	24.2	28.3
3	25	16.3	14.8	20.0	17.2	21.7	25.4
4	17	14.4	10.3	18.1	15.0	19.8	23.2
5	12	13.1	9.3	17.0	13.9	18.6	21.8
Moisture (%)		30.2	29.0	37.9	34.2	35.8	42.0
Sample Ident. A#		5270	5271	5272	5273	5274	5275

* Difference due to compression of core during extraction.

CORE STRUCTURE - SIZE ANALYSIS
AT VARIOUS GRID POSITIONS
CORES TAKEN JAN. 16, 1984

Core Grid Position: E-5

Core Depth Position;		1	2	3	4	5	6
*Core Segment Depth Based On:	Actual Core Length (cm)	0-7.7	7.7-15.4	15.4-23.1	23.1-30.8	30.8-38.5	38.5-46.
	Observed Core Depth (cm)	0-8.3	8.3-16.6	16.6-24.9	24.9-33.2	33.2-41.5	41.5-50
Tyler Mesh or Cyclone #	Micron Size	CUMULATIVE WEIGHT % PASSING SIZE					
35	420	97.5	99.3	99.5	99.7	99.7	76.3
48	297	82.9	90.9	93.5	94.6	97.2	72.1
65	210	62.4	73.1	81.3	85.6	91.3	67.0
100	149	46.1	53.8	66.0	71.4	81.0	60.5
150	105	35.0	42.2	54.6	58.5	69.3	55.0
200	74	28.4	33.6	44.9	48.1	59.5	58.9
Cyclone 1	48	25.5	29.8	41.4	44.4	54.8	46.0
2	36	22.6	26.6	37.0	39.7	49.4	42.4
3	25	20.0	24.0	33.1	35.6	44.5	38.7
4	17	18.0	22.0	30.1	32.4	40.5	35.3
5	12	16.8	20.9	28.2	30.6	38.0	33.1
Moisture (%)		40.9	46.5	51.4	48.4	53.5	48.7
Sample Ident. A#		5276	5277	5278	5279	5280	5281

* Difference due to compression of core during extraction.

CORE STRUCTURE - SIZE ANALYSIS
AT VARIOUS GRID POSITIONS
CORES TAKEN JAN. 16, 1984

Core Grid Position: J-5

Core Depth Position :		1	2	3	4	5	6
*Core Segment Depth Based On:	Actual Core Length (cm)	0-4	4-8	8-12	12-16	16-20	20-24
	Observed Core Depth (cm)	0-4.5	4.5-9	9-13.5	13.5-18	18-22.5	22.5-27
Tyler Mesh or Cyclone #	Micron Size	CUMULATIVE WEIGHT % PASSING SIZE					
35	420	86.8	99.4	39.3	24.2	24.0	25.6
48	297	84.7	97.1	34.2	17.2	16.1	18.5
65	210	81.7	92.2	30.8	11.8	10.5	12.6
100	149	79.2	87.9	28.7	8.4	6.8	8.9
150	105	76.2	84.3	27.8	6.6	5.1	6.8
200	74	72.4	81.1	26.7	5.8	4.1	5.9
Cyclone 1	48	69.5	79.3	26.2	5.3	3.6	5.2
2	36	65.4	76.6	25.5	5.0	3.2	4.7
3	25	60.6	72.5	24.3	4.6	2.8	4.1
4	17	55.9	67.3	22.8	4.3	2.5	3.6
5	12	52.7	63.3	21.7	2.7	2.4	3.3
Moisture (%)		52.4	51.2	46.4	4.9	4.2	3.9
Sample Ident. A#		5282	5283	5284	5285	5286	5287

* Difference due to compression of core during extraction.

CORE STRUCTURE - SIZE ANALYSIS
AT VARIOUS GRID POSITIONS
MARCH 26, 1984

Core Grid Position: Freeze - Thaw Core

Core Depth - cm		0-15	15-30	30-45
Mesh Or Cylone	Micron Size	CUMULATIVE WEIGHT % PASSING SIZE		
35	420	98.0	99.8	99.4
48	297	90.2	97.9	96.3
65	210	77.1	91.5	89.3
100	149	65.3	83.7	81.8
150	105	55.9	76.4	74.0
200	74	54.2	71.9	69.3
Cyclone 1	48	47.2	68.4	64.4
2	36	43.8	65.5	59.8
3	25	41.0	62.9	54.8

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APPENDIX L

PILOT PLANT RADON FLUX OBSERVATIONS CONDUCTED BY THE O.R.F. DEPARTMENT OF APPLIED PHYSICS

JOB NUMBERS 82918, 82933, 82937
AND 83933

PILOT PLANT FAILINGS FACILITY RADON FLUX OBSERVATIONS FOR THE PERIOD - JUNE 18, 1982 - NOV. 24, 1983

Submitted to:

Dr. V.I. Lakshmanan
Pilot Plant
Materials Division

WR Stott

Dr. W.R. Stott
Research Scientist
Materials Characterization Centre

October 18, 1984.

PILOT PLANT TAILINGS FACILITY

RADON FLUX OBSREVATIONS

Radon gas emanating from the tailings has been monitored on a regular basis to observe any changes as the pile ages. These data as well as a comparison with the original Midwest Project data are presented.

Radon gas was captured in an hermetically sealed metal box of known dimensions which was laid on the tailings surface. After a period of time (usually about 2 hours), the accumulated gas within the box was sampled into a standard evacuated radon cell. After waiting between 2 and 3 hours, the cell was placed in a detection unit that counted the scintillations occurring within the radon cell.

After allowing for background and corrections factors, the average radon flux over the collection time from the covered area was measured. The emanating rate was calculated knowing the volume of the box, the surface area covered, the time of collection, the counting time and the standard parameters associated with the radon cell, as follows:

$$\text{Flux pCi/m}^2\text{/s} = \frac{\text{Counts}}{T \times 4} \times \frac{V_{box}}{V_{cell}} \times \frac{1}{A_{box}} \times \frac{1}{t}$$

where:

T = counting time in minutes

V_{box} = 4 L

V_{cell} = 0.16 L

A_{box} = 0.0255 m^2

t = collection time in seconds

The original measurements taken during the Midwest Project consisted of 13 separate measurements and ranged from 29 to 214 pCi/m^2/s.

Job Numbers 83918, 82933, 82937
and 83933

Dr. V.I. Lakshmanan

With 8 layers of tailings the readings averaged 136 pCi/m^2/s.

The present sets of readings were taken from three locations on the tailings approximately 30 cm from the high side (east) - #1: near the heater; #2: in the middle; #3: on the far side from the heater).

RADON FLUX MEASUREMENTS FROM TAILINGS PILE

(pCi/m^2/s)

DATE (1982 - 1983)	LOCATION		
	#1	#2	#3
June 18, 1982	271	167	30
June 24	254	235	28
July 20	165	216	66
September 7	145	120	(7)
September 29	246	(497)	228
October 29	341	356	118
December 9	270	253	123
January 21, 1983	79	96	212
March 3, 1983	91	83	245
May 13, 1983	89	79	280
July 6, 1983	95	58	234
July 29, 1983*	60	80	224
Nov. 24, 1983	90	178	59

NOTE: The nubers in brackets seem anomalous

*The readings were taken shortly after a 10,000 litre flooding of the tailings pile.

At location 3 (farthest away from the heater), there is a trend to an increasing rate of emanate of radon from the surface of the tailings. Two of the readings have been bracketed to indicate that the data appears anamolous for reasons unknown. Also, the readings at locations 1 and 2 taken after January 21, 1983 exhibit a significant reduction from before January 21. This could be due to the fact that core holes are within approximately 20 cm of the two sampling sites and were drilled in the time period between December 9, 1982 and January 21, 1983.

FREEZE/THAW AREA

June 21, 1983	Frozen	5 pCi/m^2/s
July 7, 1983	Thawed Out	316 pCi/m^2/s
Nov. 24, 1983	Frozen	2 pCi/m^2/s

The Freeze/Thaw area is adjacent to the #3 location in the table.

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and Energy Technology
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APPENDIX M

BACTERIAL ASSESSMENT OF THE TAILINGS BED

ONTARIO RESEARCH FOUNDATION

[illegible]

MISSISSAUGA ONTARIO [illegible]

Mr. J.D. Melnbardis,
Department of Engineering & Metallurgy.

June 21, 1982

REPORT NUMBER ACS7-82379

IDENTIFICATION WO #6424

SPECIFICATIONS OF ORDER Bacterial test work on CANMET tailings.

Initially, some time was spent checking on basic methodology for work to be done with Thiobacillus ferrooxidans and Thiobacillus thiooxidans. A partial literature search was done to obtain papers on growth conditions and media used.

Five samples of the uranium tailings bed were taken using a 6 mm x 6 cm cork borer on June 9, 1982. Two samples were put into duplicate flasks of iron oxidizing medium (for detection of Thiobacillus ferrooxidans) and two samples were put into duplicate flasks of sulphur medium (for detection of Thiobacillus thiooxidans). The remaining sample was put into 50 mL of distilled water for pH determination. The pH was determined to be 8.5 The iron oxidizing medium and sulphur medium flasks were put on a gyrotary shaker at 33°C for 48 hours. At the end of 48 hours, subcultures were made to determine if any organisms were growing. (The first flasks were so cloudy from the tailings it was not possible to establish visibly if any growth was present.) No growth was observed in any flasks. We believe

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this is due to the alkaline pH of the tailing bed as the optimum pH for *Thiobacillus thiooxidans* and *Thiobacillus ferrooxidans* is in the range of 1.8 to 4.0

At the same time the pH was determined, the oxidation-reduction potential of the bed was established to be -75 mV. The optimal redox potential for *T. ferrooxidans* varies from +190 mV to +550 mV depending on the substrate that the organism is growing on.

Therefore, we believe the pH and the oxidation-reduction potential are not suitable for *T. thiooxidans* and *T. ferrooxidans* growth.

We propose to take further samples from the bed and adjust the pH to a suitable range using dilute sulphuric acid and then inoculate some of the acidified solution into both the iron oxidizing and sulphur media. These media would be incubated and subsequently examined for growth. Growth should be observed if there are dormant bacteria in the tailings bed.

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Mr. J.D. Meinbardis,
Department of Engineering & Metallurgy.

October 14, 1982

REPORT NUMBER ACS7-82563

IDENTIFICATION Work Order No. 6486

SPECIFICATIONS OF ORDER Bacterial work on CANMET tailings, Phase II.

SUMMARY

The object of this work was to determine if the bacterium Thiobacillus ferrooxidans was present and/or could grow on the CANMET uranium tailings under the pilot plant conditions. The results of this study showed that the alkalinity of the tailings was equivalent to 3.9% calcium carbonate and that 0.6% iron was present in the tailings. Unless the tailings are neutralized to pH 4.0 or less, and an external source of iron was available, Thiobacillus ferrooxidans will not grow or be able to maintain viability in the presence of the CANMET tailings. It was not possible to isolate any dormant bacteria in the tailings that could even be viable upon laboratory alteration of the tailings (i.e. the pile is sterile).

METHODS AND RESULTS

In phase II of the bacterial testing, further samples of the uranium tailings bed were taken on August 19. The first sample obtained was used to determine the alkalinity of the tailings bed. One gram of tailings was added to 100 mL of distilled water and 0.02 N sulphuric acid was used

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to titrate the sample. It was found that one gram of tailings contained the equivalent of approximately 3.9% calcium carbonate.

A portion of the tailings sample in distilled water was streaked on Difco nutrient agar plates and one of the tailings/water mixture was inoculated into 5 mL of Difco nutrient broth. No growth was observed on the nutrient plates or in the nutrient broth so it was not necessary to identify or enumerate any bacteria.

A composite tailings sample was obtained from the bed to determine (by wet weight) the iron content of the tailings. It was determined by flame atomic absorption spectrophotometry that the iron concentration was 0.6% of the total sample.

Before continuing with any more testing with the tailings, it was necessary to confirm that the stock culture of *Thiobacillus ferrooxidans*, received from the American Type Culture Collection, was viable. The stock culture was inoculated into two types of media known to support *T. ferrooxidens*. One medium was from Standard Methods 14th edition, the other was from the American Type Culture Collection (ATCC) 12th edition, referred to as media #64. The stock culture of *T. ferrooxidans* was inoculated into three tubes of each of the *Thiobacillus ferrooxidans* media and into three tubes of basal salts only (i.e. no energy source was available for the growth of *T. ferrooxidans*). It was expected that growth would be visible in both the Standard Methods and American Type Culture Collection media and no growth would be seen in the basal salts only media without the energy (iron) source.

Growth of *T. ferrooxidans* was confirmed after five days in both the Standard Methods and ATCC media incubated at room temperature; no growth was seen in the basal salt only test tubes, even after 21 days incubation. This confirmed the viability of the *T. ferrooxidans* culture.

The previous testing of the uranium tailings bed indicated that the pH of the bed was 8.5. Since this was outside the optimal pH range of 1.8 to 4.0 for *T. ferrooxidans* the pH of the tailings had to be adjusted so the bacteria would be able to reproduce in the presence of the tailings. Two

2 gram samples of tailings were added to 100 mL of distilled water and were pH adjusted, one sample to pH 3.1 and one to pH 3.6. The pH 3.1 sample was acidified with 60 mL of 0.02N H_2SO_4 and the pH 3.6 sample was acidified with 40 mL of 0.02N H_2SO_4. These acidified samples were mixed and dividied in two for duplicate sampling, therefore we had four samples in total, #1 and #2 at pH 3.6, and #3 and #4 at pH 3.1. #2 and #4 were filtered through 0.22 µm filters. Approximately one gram of each sample was recovered. These one gram samples were divided in two. 0.5 grams of #2 and #4 were put into 10 mL of ATCC #64 media and incubated at room temperature without the addition of any bacterial culture. The duplicate set of 0.5 g of #2 and #4 were also put into 10 mL of ATCC #64 media and incubated at room temperautre but in addition, 1.0 mL of viable T. ferrooxidans was added to each test tube. The samples to which both media and bacteria were added showed growth after six days. The samples incubated in media but without bacterial inoculation, did not show any growth after six days so viable T. ferrooxidans were added and six days later growth was visible. So samples #2 and #4 (pH 3.6 and 3.1 respectively) did not contain any dormant Thiobacillus forrooxidans organisms, were in the correct pH range for this organism and when media was supplied, supported T. ferrooxidans growth.

Samples #1 and #3 were also divided in two. 5 mL of #1 and #3 had 10 mL of ATCC #64 media added to them and were inoculated with 5 mL of T. ferrooxidans culture. Another 5 mL of #1 and #3 had 5 mL of T. ferrooxidans added to them but no ATCC #64 media was added. The #1 and #3 samples to which both media and cells were added did show growth, but the #1 and #3 samples with cells but without media did not grow, suggesting that either the basal salts and/or the iron components of the ATCC #64 media were not present in sufficient concentration in the uranium tailings to support T. ferrooxidans growth.

To 3 mL of #1 and #3 was added 7 mL of the basal salts found in the Standard Methods media. These test tubes were inoculated with 1 mL of viable Thiobacillus ferrooxidans organisms. This test was conducted to see if the bacteria could grow on the tailings if basal salts (but no additional iron source) were available. No growth was visible. This suggested that the iron (Fe) concentration in the uranium tailings was not sufficient to meet the bacteria's requirements.

Five levels of iron in the form of ferrous sulphate (Fe $SO_4 \cdot 7H_2O$) were tested to determine the minimal iron concentration needed to sustain *Thiobacillus ferrooxidans*. 0.5, 1, 3, 5 and 10 percent ferrous sulphate plus basal salts and *T. ferrooxidans* cells were combined and incubated a room temperature. Growth in the 1% $FeSO_4 \cdot 7H_2O$ test tubes was slight and increased at 3 to 10% $FeSO_4 \cdot 7H_2O$. No growth was seen at the 0.5% level of $FeSO_4 \cdot 7H_2O$. Since a composite sample of the uranium tailings showed only 0.6% iron on analysis, we concluded that there is insufficient iron present in the tailings to support *T. ferrooxidans*.

CONCLUSIONS

In summary, no bacterial organisms, *Thiobacillus ferrooxidans* or otherwise, could be detected in the uranium tailings. We found the tailings to be too alkaline to support *T. ferrooxidans* without neutralization and there was insufficient iron available to these bacteria for an energy source.

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APPENDIX I

Thiobacillus ferrooxidans Media

American Type Culture Collection #64 media.

Solution A: (Basal Salts)

$(NH_4)_2SO_4$	0.4 g
KH_2PO_4	0.2 g
$MgSO_4 \cdot 7H_2O$	0.08 g
Distilled water	400 mL

Solution B: (Energy Source)

$FeSO_4 \cdot 7H_2O$	10.0 g
1N H_2SO_4	1.0 mL
Distilled water	100 mL

Mix A and B. pH should be about 2.8.

Standard Methods (14th edition) Media

(#42 Iron Oxidizing Medium)

Basal salts:

$(NH_4)_2SO_4$	3.0 g
KCl	0.1 g
K_2HPO_4	0.5 g
$MgSO_4 \cdot 7H_2O$	0.5 g
$Ca(NO_3)_2$	0.01 g
H_2SO_4, 10N	1.0 mL
Distilled water	700 mL

Energy Source: 14.74% w/v solution $FeSO_4 \cdot 7H_2O$ 300 mL

Separately sterilize the basal salts and energy source and combine when cool. The medium can be stored for at least 2 weeks in the refrigerator. The pH should be 3.0 to 3.6.

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Mr. E. VanHuyssteen,
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May 12, 1983.

REPORT NUMBER BCE7-83228

IDENTIFICATION Work Order No. 11520

SPECIFICATIONS OF ORDER Bacterial Assessment of CANMET Tailings.

SUMMARY

The objective of this assessment was to determine if the bacterium Thiobacillus ferrooxidans was present and/or could grow on the CANMET uranium tailings under the present pilot plant conditions. The results of this study showed that 0.55% iron was present in a composite tailing sample. Unless the tailings are neutralized to pH 4.0 or less, and an external source of iron and nutrients was available, Thiobacillus ferrooxidans will not grow or be able to maintain viability on the CANMET tailings. The tailings are not toxic to Thiobacillus ferrooxidans. It was possible to isolate two cultures with different colony morphology, both Gram negative rods from the tailings and the run-off water.

METHOD AND RESULTS

In this phase of the bacterial testing of the CANMET tailings, composite

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samples of the bed and run-off water were taken aseptically on April 18, 1983.

A portion of the tailings sample in sterile distilled water was streaked on DIFCO nutrient agar plates and some of the tailings/water slurry was inoculated into 5 ml DIFCO nutrient broth. This was also done with the run-off water. Turbidity (growth) was found in both inoculated tubes of broth and two types of colonies on the DIFCO agar plates. Gram stains were made and observed microscopically. The bacteria observed were Gram negative rods; one colony had shorter rods than the other. No attempt at typing of the bacteria has been made but no growth was observed when these bacteria were inoculated into Thiobacillus ferrooxidans media thus confirming that T. ferrooxidans is not present in the tailings pile.

A composite tailings sample was obtained from the bed to determine the iron content of the tailings. It was determined by flame atomic absorption spectrophotometry that the iron concentration was 0.55% of the total sample.

Before continuing with more testing, it was confirmed that the stock culture of Thiobacillus ferrooxidans was viable. The stock culture was inoculated into four tubes of the American Type Culture Collection (ATCC) #64 media and one tube of basal salts only (i.e. no energy source was available for the growth of T. ferrooxidans). It was expected that growth would be visible in the ATCC #64 media and not in the basal salt tube. Control tubes were also included to confirm the sterility of the #64 media and basal salts.

Growth of T. ferrooxidans was confirmed after five days in the ATCC #64 media (at room temperature); no growth was observed in the basal salt or control tubes. This confirmed the viability of the T. ferrooxidans culture.

pH testing of the uranium tailings bed indicated that the pH was 8.4. The pH of the run-off water was 8.0. Since this was outside the optimal pH range of 1.8 to 4.0 for T. ferrooxidans, the pH of the tailings was adjusted so the bacteria would be able to maintain their viability in the presence of the tailings.

2 gram samples of tailings were added to 100 ml of distilled water and were pH adjusted, one sample to pH 3.1 and one to pH 3.4. The pH 3.1 sample was acidified with 120 ml of 0.02N H_2SO_4 and the pH 3.4 sample was acidified with 100 ml of 0.02N H_2SO_4. These acidified samples were mixed and divided in two for duplicate sampling, therefore we had four samples in total, #1 and #2 at pH 3.4, and #3 and #4 at pH 3.1. #2 and #4 were filtered through 0.22 μm filters. Approximately one gram of each sample was recovered. These one gram samples were divided in two. 0.5 grams of #2 and #4 were put into 10 ml of ATCC #64 media and incubated at room temperature without the addition of any bacterial culture. The duplicate set of 0.5 g of #2 and #4 were also put into 10 ml of ATCC #64 media and incubated at room temperature but in addition, 1.0 ml of viable T. ferrooxidans was added to each test tube. The samples to which both media and bacteria were added showed growth after six days. The samples incubated in media but without bacterial inoculation, did not show any growth after six days so viable T. ferrooxidans were added and six days later growth was visible. So samples #2 and #4 (pH 3.4 and 3.1 respectively) did not contain any dormant Thiobacillus ferrooxidans organisms, were in the correct pH range for this organism and when media was supplied, supported T. ferrooxidans growth.

Samples #1 and #3 were also divided in two. 5 ml of #1 and #3 had 10 ml of ATCC #64 media added to them and were inoculated with 5 ml. of T. ferrooxidans culture. Another 5 ml of #1 and #3 had 5 ml of T. ferrooxidans added to them but no ATCC #64 media was added. The #1 and

#3 samples to which both media and cells were added did show growth, but the #1 and #3 samples with cells but without media did not grow, suggesting that either the basal salts and/or the iron components of the ATCC #64 media were not present in sufficient concentration in the uranium tailings to support *T. ferrooxidans* growth.

As previously determined, the iron content of the uranium tailings was too low to support *T. ferrooxidans* without an external iron source. At least 1% of $FeSO_4 \cdot 7H_2O$ is required to maintain *T. ferrooxidans*. We also suspect, due to the fact that distilled water and tailings did not support the growth of an inoculation of *T. ferrooxidans*, that the minimal nutritional requirements of the bacteria are not available in the tailings and the bacteria will not grow without supplement.

CONCLUSIONS

In summary, no *T. ferrooxidans* could be detected in the tailings to date. We found the tailings to be too alkaline, have too low an iron concentration available for an energy source and lacking in essential nutrients to support *T. ferrooxidans*. However, some bacteria were able to colonize the tailings and run-off water and these bacteria were found to be Gram negative rods.

FUTURE WORK

Further sampling and bacterial assessment for the CANMET tailing programme will be carried out at the end of July 1983. This work will monitor the tailings bed and the freezes box area to determine what microbiological change occurred in the bed as conditions were made more acidic.

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August 18, 1983

REPORT NUMBER BCE7-83409

IDENTIFICATION Work Order No. 11520

SPECIFICATIONS OF ORDER Bacterial assessment of CANMET tailings.

SUMMARY

The objective of this assessment was to determine if the bacterium Thiobacillus ferrooxidans was present and/or could grow on the CANMET uranium tailings under the pilot plant conditions of July 1983. The results of this study showed that 0.52% iron was present in a composite tailings bed sample and 0.52% iron was present in a composite sample taken from the freezer box area of the tailings bed.

Unless the tailings are neutralized to pH 4.0 or less, and an external source of iron and nutrients is available, Thiobacillus ferrooxidans will not grow or be able to maintain viability on the CANMET tailings. The tailings are not toxic to Thiobacillus ferrooxidans. It was possible to isolate cultures with different colony morphology from the tailings, seepage and run-off water.

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METHOD AND RESULTS

In this phase of the bacterial testing of the CANMET tailings, composite samples of the bed and the freezer box tailings were taken. In addition, samples of the run-off and seepage water were collected, aseptically. The sampling was conducted on July 25, 1983.

A portion of the bed and freezer box samples in distilled water was streaked on DIFCO nutrient agar plates and some of each tailing/water slurry was inoculated into 5 mL nutrient broth. Run-off water and seepage water was also streaked on nutrient agar plates and inoculated into nutrient broth. Turbidity was observed in all of the inoculated nutrient broth tubes and two colony types were seen on the agar plates. Gram stains were made and observed microscopically. The bacteria observed were Gram negative rods; some rods were shorter than others, some were in chains, while others were single. No attempt at typing of the bacteria has been made, but no growth was observed when these bacteria were inoculated into *Thiobacillus ferrooxidans* media (ATCC No. 64 media) confirming that *T. ferrooxidans* is not present in the tailings pile.

A composite tailings sample was obtained from the bed and the freezer box to determine the iron content of the tailings. It was determined by flame atomic absorption spectrophotometry that the iron content of the bed was 0.52% of the total sample and the iron content of the tailings in the freezer box was 0.52% of the total composite sample.

Before continuing with the testing of the tailings we confirmed that our stock culture of *Thiobacillus ferrooxidans* was viable. The stock culture was inoculated into four tubes of the American Type Culture Collection (ATCC) No. 64 media and one tube basal salts only (i.e. no energy source was available for the growth of *T. ferrooxidans*). It was expected that growth would be visible in the ATCC No. 64 media and not in the basal salt tube. Contol tubes were also included to confirm the sterility of the No. 64 media and basal salts.

Growth of _T. ferrooxidans_ was confirmed after five days in the ATCC No. 64 media (at room temperature); no growth was observed in the basal salt or control tubes. This confirmed the viability of the _T. ferrooxidans_ culture.

pH testing of the uranium tailings bed indicated the pH was 8.4 The pH of the tailings from inside the freezer box was 8.85. The run-off water had a pH of 8.08 and the pH of the seepage water was 8.05. Since these pHs were outside the optimal pH range of 1.8 to 4.0 for _T. ferrooxidans_, the pH of the tailings was adjusted so the bacteria would be able to maintain their viability in the presence of the CANMET tailings.

Two gram samples of tailings, from the bed and from the freezer box, were added to 100 mL distilled water and were pH adjusted. The duplicate samples of tailings from the bed were adjusted to pH 3.0 and 3.6 while the duplicate samples of tailings from the freezer box were adjusted to 3.0 and 3.4. All pH adjustments were made with 0.02N H_2SO_4. The acidified samples were mixed and divided in two for duplicate sampling. Therefore, we had 8 samples.

A-1 and A-2	Tailings bed at pH 3.0
B-1 and B-2	Tailings bed at pH 3.6
C-1 and C-2	Tailings freezer box at pH 3.0
D-1 and D-2	Tailings freezer box at pH 3.4

A-1, B-1, C-1 and D-1 were filtered through 0.22 μm filters. Approximately 1 gram of each sample was recovered. These one gram samples were divided in two.

0.5 gram of each sample was put into 10 mL ATCC No. 64 media and incubated at room temperature without the addition of any bacterial culture. The duplicate set of 0.5 g samples was also put in 10 mL ATCC No. 64 media and incubated at room temperature but in addition, 1.0 mL of viable _T. ferrooxidans_ was added to each test tube. The samples to which both media and bacteria were added showed growth after seven days. The samples incubated in media but without bacterial inoculation, did not show any growth after six days, so viable T. ferrooxidans were added and six days later growth was visible. So samples A-1, B-1, C-1, D-1 did not contain any dormant Thiobacillus ferrooxidans, were in the correct pH range for this organism and, when media was supplied, supported T. ferrooxidans growth.

Samples A-2, B-2, C-2 and D-2 were also divided in two. 5 mL of each sample was added to 10 mL ATCC No. 64 media and were inoculated with 5 mL of Thiobacillus ferrooxidans culture. Another 5 mL of each sample had 5 mL T. ferrooxidans added but no ATCC No. 64 media was added. The samples to which both media and cells were added did show growth. The samples that had cells but no media did not support growth, suggesting that either the basal salts and/or the iron content of the ATCC media was not present in sufficient concentration in the uranium tailings to support T. ferrooxidans growth.

As previously determined, the iron content of the uranium tailings was too low to support T. ferrooxidans without an external source. We also suspect, due to the fact that distilled water and tailings did not support the growth of an inoculum of T. ferrooxidans, that the minimal nutritional requirements of the bacteria are not available in the tailings and the bacteria will not grow without supplement.

CONCLUSIONS

In summary, no T. ferrooxidans could be detected in the tailings to-date. We found the tailings to be too alkaline, have too low an iron concentration available as an energy source and lacking in essential nutrients to support T. ferrooxidans. However, some bacteria were able to colonize the tailings and run-off and seepage water and these bacteria were found to be Gram negative rods.

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Canada Centre for Mineral
and Energy Technology
Final Report

APPENDIX N

VARIATION IN THE U, As, Ni, AND Ra-226 CONTENT OF CORES WITH DEPTH

ORI

VARIATION IN U, As, Ni, & Ra CONTENT WITH DEPTH CORE PROFILE ANALYSES

Cores Taken March 31, 1982

Element	% U				% As				% Ni				TOTAL $pCi^{226}Ra/g$			
Core Grid Position	B1	B9	F1	F9	B1	B9	F1	F9	B1	B9	F1	F9	B1	B9	F1	F9
Top	0.10	0.081	0.071	0.24	1.60	1.99	1.43	2.40	1.06	1.24	0.85	1.34	2234	4343	4680	5139
	0.087	0.038	0.076	0.11	2.00	1.77	2.18	2.41	1.19	1.03	1.35	1.33	2833	4413	3885	3820
Depth	0.04	0.03	0.10	0.03	1.98	2.18	2.77	1.70	1.29	1.30	1.54	0.65	2327	3169	3889	4869
	0.05	0.09	0.05	0.06	1.88	2.29	2.08	2.10	1.11	1.35	1.19	1.10	2561	2021	4245	4656
	0.24	0.11	0.08	0.05	2.25	2.15	1.80	2.15	1.38	1.22	1.04	0.92	1225	2997	3538	4967
Bottom	0.23	0.062	0.21	0.05	2.68	1.55	2.36	2.11	1.63	1.95	1.29	0.94	4844	3494	4089	4076
Core Length (cm)	34	34	15	15	34	34	15	15	34	34	15	15	34	34	15	15

ORI

VARIATION IN U, As, Ni, & Ra CONTENT WITH DEPTH CORE PROFILE ANALYSES

Cores Taken May 31, 1982

Element	% U				% As				% Ni				pCi ^{226}Ra/g (TOTAL)			
Core Grid Position	B3	B7	H1	H9	B3	B7	H1	H9	B3	B7	H1	H9	B3	B7	H1	H9
Top	0.47	0.22	0.31	0.22	2.28	2.79	3.07	2.05	1.53	1.71	1.64	1.11	3,195	3,199	3,223	2,319
	0.15	0.07	0.33	0.13	1.96	2.08	2.29	2.31	1.30	1.28	1.34	1.45	2,603	3,380	3,359	3,952
	0.06	0.04	0.14	0.16	1.87	1.50	1.42	2.70	1.21	0.86	0.85	1.46	3,726	1,840	2,836	3,895
Depth ↓	0.13	0.07	0.06	0.07	2.37	1.64	1.20	2.40	1.52	1.05	0.72	1.47	4,032	4,827	3,019	4,228
	0.12	0.09	0.12	0.07	2.26	1.79	2.52	2.03	1.39	1.08	1.34	1.07	3,323	2,626	3,563	2,566
Bottom	0.16	0.16	0.14	0.10	1.83	1.53	2.30	1.64	1.14	0.95	1.35	1.30	3,041	3,451	3,949	2,844
Core Length (cm)	34	34	15	15	34	34	15	15	34	34	15	15	34	34	15	15

CORE ANALYSIS PROFILE
VARIATION IN U, As, Ni & Ra CONTENT WITH DEPTH
CORES TAKEN JULY 26, 1982

Element		U (%)				As (%)				Ni (%)				Ra-226 (pCi/g) (TOTAL)			
Grid Position		C-1	C-9	G-1	G-9	C-1	C-9	G-1	G-9	C-1	C-9	G-1	G-9	C-1	C-9	G-1	G-9
Top	1	0.18	0.11	0.28	0.19	2.37	2.22	2.24	2.89	1.34	1.27	1.27	1.71	2531	1861	800	2801
↑	2	0.06	0.04	0.37	0.03	1.58	2.15	2.61	1.99	0.92	1.23	1.35	1.29	2932	2407	1119	1595
	3	0.04	0.04	0.34	0.09	1.67	2.75	2.70	2.06	1.01	1.35	1.47	1.64	3267	2825	1151	3462
	4	0.09	0.14	0.39	0.26	2.36	2.54	2.41	2.43	1.26	1.42	1.46	1.59	3884	3565	1235	2726
Depth	5	0.33	0.14	0.50	0.13	2.05	1.74	2.46	2.81	1.06	1.21	1.32	1.72		2518	2377	2744
	6	0.19	0.06	0.26	0.32	2.01	2.17	2.83	2.63	1.05	1.34	1.52	1.42		3052	4258	3298
↓	7	0.27	0.30	NA	NA	1.47	1.87	NA	NA	0.80	1.06	NA	NA	2645	3023	NA	NA
Bottom	8	0.15	0.39	NA	NA	1.11	2.00	NA	NA	0.69	1.23	NA	NA	2565	4727	NA	NA
Core Length(cm)		34	34	15	15	34	34	15	15	34	34	15	15	34	34	15	15

NA = Not Applicable

CORE ANALYSIS PROFILE
VARIATION IN U, As, Ni & Ra CONTENT WITH DEPTH
CORES TAKEN JANUARY 5, 1983

Element	U(%)				As(%)				Ni(%)				TOTAL Ra-226 (pCi/g)			
Grid Position	C-2	C-7	G-2	G-7	C-2	C-7	G-2	G-7	C-2	C-7	G-2	G-7	C-2	C-7	G-2	G-7
Top 1	0.27	0.17	0.21	0.15	1.64	2.44	2.00	2.74	0.98	1.37	1.21	1.60	1161	2.34	3364	4745
2	0.22	0.07	0.17	0.13	2.35	2.00	2.64	2.74	1.46	1.09	1.47	1.50	2821	2215	4106	6920
3	0.10	0.07	0.19	0.14	1.59	2.00	2.43	1.81	0.98	1.14	1.36	1.04	4506	2735	4525	3003
4	0.21	0.11	0.40	0.21	2.22	2.00	2.71	2.76	1.24	1.22	1.61	1.51	4322	3027	6762	5132
5	0.31	0.77	0.58	0.27	2.15	3.18	2.74	2.31	1.17	2.06	1.32	1.25	2599	3144	3769	4034
6	0.27	0.45	0.48	0.33	2.12	1.99	2.58	2.79	1.19	1.22	1.40	1.33	2431	4168	4339	4072
7	0.44	0.41	----	----	1.76	1.96	----	----	1.05	1.21	----	----	2311	4782	----	----
Bottom 8	0.28	0.31	----	----	1.73	1.80	----	----	1.01	1.09	----	----	2195	4471	----	----
Length(cm)	55.9	50.8	34.3	34.3	55.9	50.8	34.3	34.3	55.9	50.8	34.3	34.3	55.9	50.8	34.3	34.3

CORE ANALYSIS PROFILE

VARIATION IN U, As, Ni & Ra CONTENT WITH DEPTH

CORES TAKEN APRIL 5, 1983

ELEMENT	U (%)				As (%)				Ni (%)				Ra-226 (pCi/g) (TOTAL)			
Grid Position	BC 2.5	BC 7.5	GH 2.5	GH 7.5	BC 2.5	BC 7.5	GH 2.5	GH 7.5	BC 2.5	BC 7.5	GH 2.5	GH 7.5	BC 2.5	BC 7.5	GH 2.5	GH7.5
1	0.30	0.19	0.56	0.27	1.74	3.04	2.64	2.24	1.15	1.73	1.51	1.39	2973	3333	5486	4206
2	0.16	0.07	0.34	0.12	1.89	1.93	2.56	2.75	1.25	1.25	1.41	1.52	2137	3016	4703	5554
3	0.10	0.06	0.33	0.16	1.57	2.17	3.22	2.46	0.99	1.20	1.68	1.54	3672	4072	1012	4644
4	0.14	0.14	0.16	0.35	2.05	2.05	2.73	2.76	1.26	1.19	1.55	1.61	1044	3221	3687	7113
5	0.31	0.18	0.44	0.23	2.49	1.61	2.69	2.61	1.32	0.95	1.58	1.53	2587	2557	2336	5399
6	0.19	0.37	0.48	0.41	2.00	1.41	2.88	2.77	1.22	0.91	1.53	1.59	2258	2807	4967	5073
7	0.68	0.53	-	-	1.92	1.96	-	-	1.15	1.18	-	-	2386	1785	-	-
8	0.34	0.28	-	-	2.00	1.82	-	-	1.16	1.15	-	-	2870	3417	-	-
Core Length(cm)	52.4	49.0	30.0	30.4	52.4	49.0	30.0	30.4	52.4	49.0	30.0	30.4	52.4	49.0	30.0	30.4

Variation in the Arsenic and Nickel Content with Depth
of Cores Extracted on July 26, 1983

Core Grid Position	As(%)					Ni(%)				
	C-2	C-7	G-2	G-7	F.S.*	C-2	C-7	G-2	G-7	F.S.*
Top 1	1.29	1.95	1.63	2.67	1.81	0.78	1.05	1.01	1.47	1.11
2	1.15	1.91	2.80	1.70	2.78	0.74	1.34	1.41	1.18	1.36
3	1.55	1.67	2.20	1.50	1.76	1.02	0.95	1.25	1.00	1.15
4	1.65	1.87	2.06	2.59	2.11	1.18	1.01	1.25	1.44	1.21
5	1.76	1.72	2.70	2.08	1.95	1.52	1.12	1.49	1.01	1.13
6	1.09	1.57	2.26	2.60	1.63	0.90	0.97	1.05	1.17	1.00
7	1.45	2.28	-	-	1.93	0.92	1.19	-	-	1.14
8	1.20	1.48	-	-	1.80	0.93	0.88	-	-	0.98
Bottom										
Core Length (cm)	48.0	60.0	34.5	30.0	46.4	48.0	60.0	34.5	30.0	46.4

*Freeze Section

Variation in the Uranium Content of Cores Extracted on July 26, 1983

Core Grid Position	U(%)				
	C-2	C-7	G-2	G-7	F.S.*
Top 1	0.19	0.17	0.40	0.14	0.19
2	0.30	0.07	0.15	0.10	0.19
3	0.41	0.06	0.30	0.13	0.14
4	0.56	0.14	0.35	0.27	0.43
5	0.54	0.49	0.33	0.31	0.34
6	0.34	0.42	0.54	0.47	0.66
7	0.58	0.42	-	-	0.38
Bottom 8	0.20	0.17	-	-	0.23
Core Length (cm)	48.0	60.0	34.5	30.0	46.4

*Freezer Section

Variation in the Ra-226 Content with Depth in Cores Extracted on July 26, 1983

Core Grid Position	$T^{226}Ra$(pCi/g)				
	C-2	C-7	G-2	G-7	F.S.*
Top 1	2376	2902	3739	3720	3587
2	3595	3899	5431	4179	4068
3	3789	5430	3055	2683	5365
4	3208	3620	4229	7058	4611
5	3748	3738	5752	5134	2890
6	1990	2721	4478	3538	3270
7	1851	4531	-	-	4470
Bottom 8	3074	3511	-	-	3036
Core Length (cm)	48.0	60.0	34.5	30.0	46.4

*Freezer Section

VARIATION IN URANIUM, RADIUM, ARSENIC AND NICKEL IN TAILINGS CORES

CORES TAKEN JANUARY 16, 1984

		U %							Ra pCi/g						
CORE GRID Position		B-1.5	B-8.5	H-1.5	H-8.5	B-5	E-5	J-5	B-1.5	B-8.5	H-1.5	H-8.5	B-5	E-5	J-5
Top	1	0.420	0.190	0.330	0.200	0.330	0.230	0.420	2736	2798	6564	4119	3036	3258	5781
	2	0.100	0.090	0.150	0.110	0.080	0.080	0.270	2427	3403	6387	4621			8570
	3	0.100	0.100	0.460	0.240	0.070	0.200	NSS	2048	3884	5573	6881	2332	3939	4446
	4	0.130	0.340	0.340	0.250	0.120	0.290	0.005*	2210	4177	7918	3896			312.8*
	5	0.180	0.210	0.530	0.360	0.700	0.300	TR*	1773	2339	5448	5326	3442	2035	87.3*
Bottom	6	0.340	0.310	0.230	0.250	0.410	0.262	TR*	1864	2415	2830	2931			63.0*
Core length cm		58	58	40	60	61	27	27	58	58	40	60	61	27	27

		As %							Ni %						
Core Grid Position		B-1.5	B-8.5	H-1.5	H-8.5	B-5	E-5	J-5	B-1.5	B-8.5	H-1.5	H-8.5	B-5	E-5	J-5
Top	1	1.20	2.82	2.85	2.82	2.20	2.14	3.98	0.44	1.51	1.17	1.15	0.98	1.10	1.92
	2	2.62	4.02	3.56	2.85	1.63	2.51	2.74	1.39	1.97	1.44	1.34	0.90	1.17	1.58
	3	1.96	2.18	3.17	3.02	2.32	2.37	NSS	0.99	0.97	1.57	1.43	1.27	1.14	NSS
	4	2.22	2.70	2.83	3.22	3.52	2.60	0.03*	1.13	1.35	1.25	1.42	1.72	1.26	0.04*
	5	1.77	2.93	2.90	3.22	3.02	2.59	NIL*	0.93	1.59	1.29	1.38	1.42	1.07	0.01*
Bottom	6	1.90	1.79	1.56	1.60	2.51	1.87	NIL*	0.94	0.82	0.65	0.64	1.14	0.79	0.01*
Core length cm		58	58	40	60	61	27	27	58	58	40	60	61	27	27

NSS - Not sufficient sample
TR - Trace
* - Sand Bank

RADIUM ANALYSES OF CORE SIZED FRACTIONS, SAMPLED JANUARY 16, 1984

Core	Section T=Top M=Mid-Section B=Bottom	Whole Core *	Size Fraction - Micron -74	 -74 +12	 -12
B-1.5	T	2582	806.8	3156	9295
	M	2129	1353	1880	9682
	B	1818	682.1	1295	8273
B-8.5	T	3100	782.8	2357	11232
	M	4030	616.3	2305	11559
	B	2377	717.7	2420	11288
H-1.5	T	6476	2005	2290	13957
	M	6746	1436	3907	14446
	B	4139	796	2466	15751
H-8.5	T	4370	922.8	1729	13303
	M	5388	798.6	2145	12110
	B	4128	658.0	1840	10567
B-5	T	3036	618.4	2193	11001
	M	2332	597.8	1751	11588
	B	3442	899.5	2060	11886
E-5	T	3258	979.4	2464	15044
	M	3939	1366	2375	12906
	B	2035	778.3	1544	11929
J-5	T	7175	1675	2775	14481
	M**	2379	128.2	111.3	9998
	B**	75	37.3	69.8	312.3

* See previous tabulation

** Includes bedding sand

RADIUM ANALYSES OF FREEZE - THAW CORE - TAKEN MARCH 26, 1984

	Ra-226 (pCi/g)		
	Whole core	+74 Micron fraction	-74 Micron fraction
Top	3841	912.5	1867
Mid-Section	4053	786.8	1652
Bottom	3980	1152	1706

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APPENDIX O

Fe, Na, K, Mg, Ca, Total SO_4", and Soluble SO_4" ANALYSES OF SELECTED CORE SEGMENTS

ORI

CORE C1 (extracted July 26, 1982)

SEGMENT	ELEMENT %						
	Fe	Na	K	Mg	Ca	$SO_4^=$Total	$SO_4^=$Soluble
Top 1*	0.81	<0.1	0.36	0.16	4.22	10.3 (w/w)	8.99 (w/w)
3	0.70	<0.1	0.55	0.24	6.02	12.7 (w/w)	10.9 (w/w)
5	0.66	<0.1	0.42	0.25	7.74	15.0 (w/w)	14.3 (w/w)
Bottom 7	0.60	<0.1	0.44	0.19	4.41	8.5 (w/w)	8.1 (w/w)

* Arranged sequentially according to depth

ORI

CORE G9 (extracted July 26, 1982)

SEGMENT		ELEMENT %								
		Fe	Na	K	Mg	Ca	$SO_4^=$Total		$SO_4^=$Soluble	
Top	1*	1.55	<0.1	0.62	0.35	11.47	22.1	(w/w)	21.1	(w/w)
	3	1.06	<0.1	0.79	0.38	10.06	18.8	(w/w)	18.1	(w/w)
	5	1.63	<0.1	0.78	0.44	12.98	28.2	(w/w)	25.4	(w/w)

* Arranged sequentially according to depth

CORE C2.25 (extracted January 5, 1983)

SEGMENT	ELEMENT %						
	Fe	Na	K	Mg	Ca	$SO_4^=$Total	$SO_4^=$Soluble
Top 1*	0.85	0.14	0.33	0.16	4.08	10.1 (w/w)	8.59 (w/w)
3	0.67	0.06	0.56	0.23	5.55	12.2 (w/w)	11.4 (w/w)
5	0.79	0.06	0.46	0.25	7.05	16.4 (w/w)	14.2 (w/w)
Bottom 7	0.81	0.06	0.65	0.25	6.07	12.8 (w/w)	10.2 (w/w)

* Arranged sequentially according to depth

CORE G7.25 (extracted January 5, 1983)

SEGMENT	ELEMENT %						
	Fe	Na	K	Mg	Ca	$SO_4^=$Total	$SO_4^=$Soluble
Top 1*	1.67	0.03	0.59	0.36	11.55	17.6 (w/w)	15.4 (w/w)
3	0.91	0.02	0.71	0.31	7.27	14.1 (w/w)	14.0 (w/w)
5	1.55	0.04	0.96	0.48	14.04	29.7 (w/w)	23.7 (w/w)

* Arranged sequentially according to depth

ORI

CORE GH 7.5 (extracted April 5, 1983)

SEGMENT	ELEMENT %								
	Zn	Cu	Na	Fe	Mg	Pb	Ni	Ca	K
Top 1*	0.072	0.061	0.15	1.52	0.33	0.27	1.20	9.11	0.83
3	0.060	0.11	0.16	1.37	0.39	0.30	1.36	11.2	1.12
5	0.047	0.11	0.23	1.72	0.52	0.29	1.41	16.6	1.27

* Arranged sequentially according to depth

Core (extracted July 26, 1983)

Core Grid Position	Normal Bed Position C2 Analyses					Freeze-Thaw Bed Analyses				
	%Fe	%Ca	%Mg	%K	%Na	%Fe	%Ca	%Mg	%K	%Na
Top 1	0.64	2.86	0.14	0.43	0.11	1.03	5.23	0.21	0.57	0.08
2	0.74	3.96	0.19	0.71	0.11	1.41	10.65	0.34	0.63	0.08
3	0.85	4.30	0.21	0.75	0.14	1.06	8.14	0.31	0.87	0.09
4	0.83	5.12	0.20	0.67	0.15	1.14	12.35	0.38	0.91	0.23
5	0.98	5.10	0.22	0.69	0.16	1.06	10.6	0.35	0.8	0.2
6	0.70	6.27	0.22	0.58	0.15	0.95	7.63	0.35	1.12	0.27
7	0.81	5.46	0.25	0.80	0.16	1.29	10.99	0.39	1.05	0.21
Bottom 8	1.01	7.52	0.28	0.82	0.33	1.53	16.48	0.50	0.83	0.30

ORI

Cores (extracted from the Normal Bed and from the Freeze Thaw Bed July 26, 1983)

Depth	Chloride (mg/g)		Sulphate (mg/g)		Carbonate (mg/g)		Bicarbonate (mg/g)	
	Core C-2	Freezer	Core C-2	Freezer	Core C-2	Freezer	Core C-2	Freezer
1	<0.1	<0.1	98.9	65.7	2.5	<0.1	18.2	11.7
2	<0.1	<0.1	159	83.2	15.4	<0.1	54.6	24.2
3	<0.1	<0.1	148	96.6	5.5	<0.1	47.8	21.5
4	<0.1	<0.1	223	109	12.8	<0.1	63.6	29.7
5	<0.1	<0.1	219	98.6	21.5	0.84	43.4	38.1
6	<0.1	0.2	125	103	24.0	8.64	24.0	44.1
7	<0.1	0.3	167	77.6	21.8	11.2	21.8	41.7
8	<0.1	<0.1	227	123	64.6	11.8	64.6	53.7

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APPENDIX P

X-RAY DIFFRACTION DATA

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 29.796  2.9985    120
 31.121  2.8737     32
 36.639  2.4527    160 ·
 39.552  2.2784    150 ·
 40.336  2.2360     72 ·
 40.467  2.2290     64
 42.542  2.1250    190 ·
 45.886  1.9776     70 ·
 50.229  1.8163    284 ·
 54.963  1.6705     78 ·
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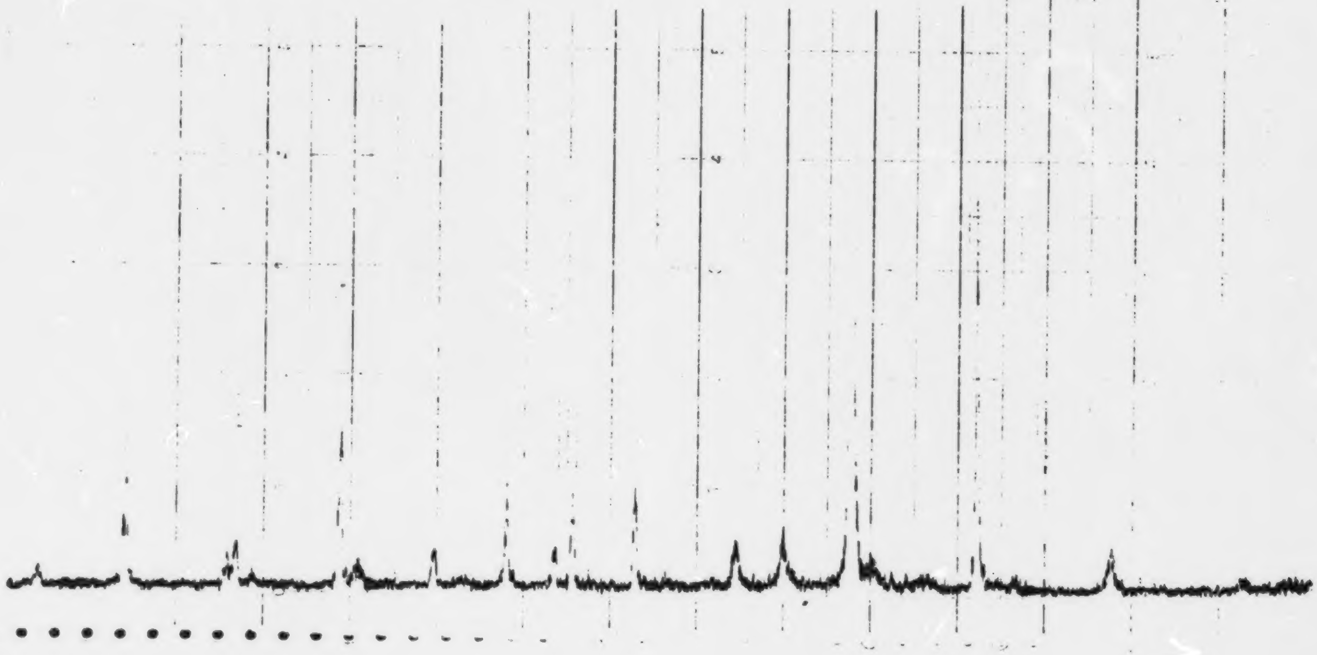

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 42.560  2.1241   148 ·
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 50.351  1.8122   188 ·
 54.974  1.6703   124 ·
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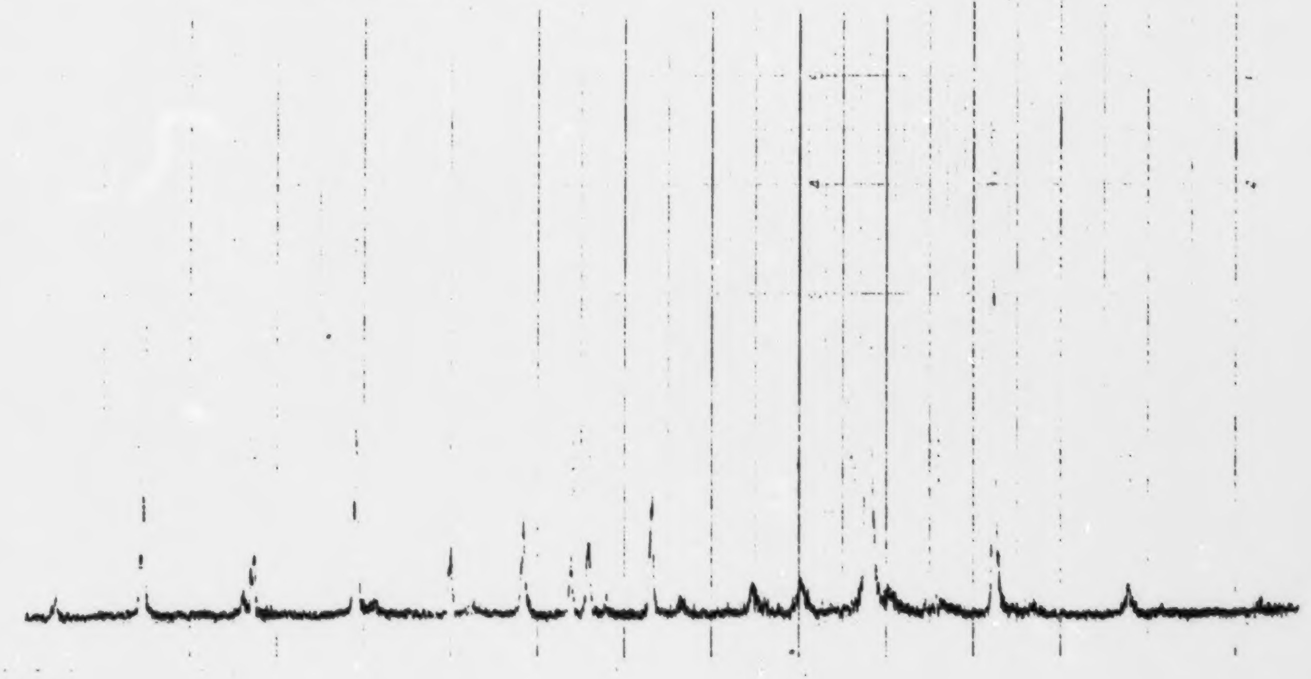

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 31.952   2.8009     114 .
 36.662   2.4512     150 .
 39.595   2.2766     166 .
 40.413   2.2319      63 .
 42.549   2.1246     168
 45.882   1.9778      74 .
 50.222   1.8166     254 .
 50.342   1.8125     138
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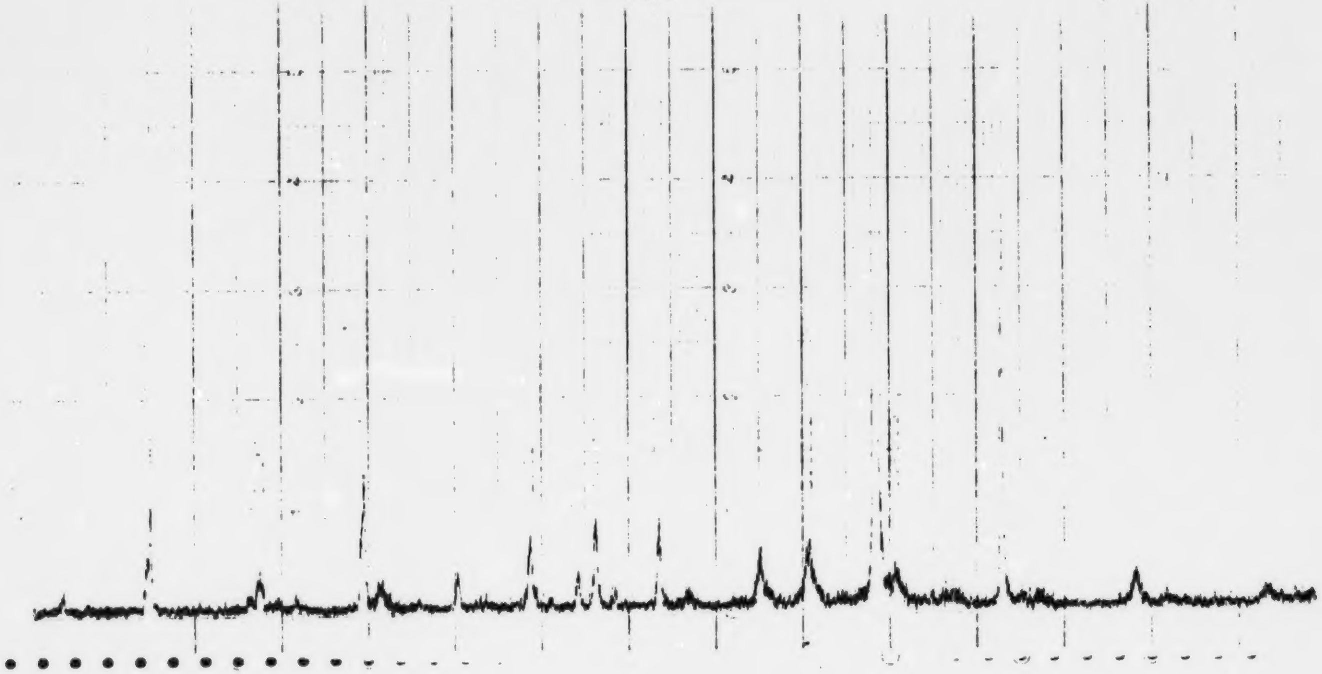

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  45.880  1.9778      69
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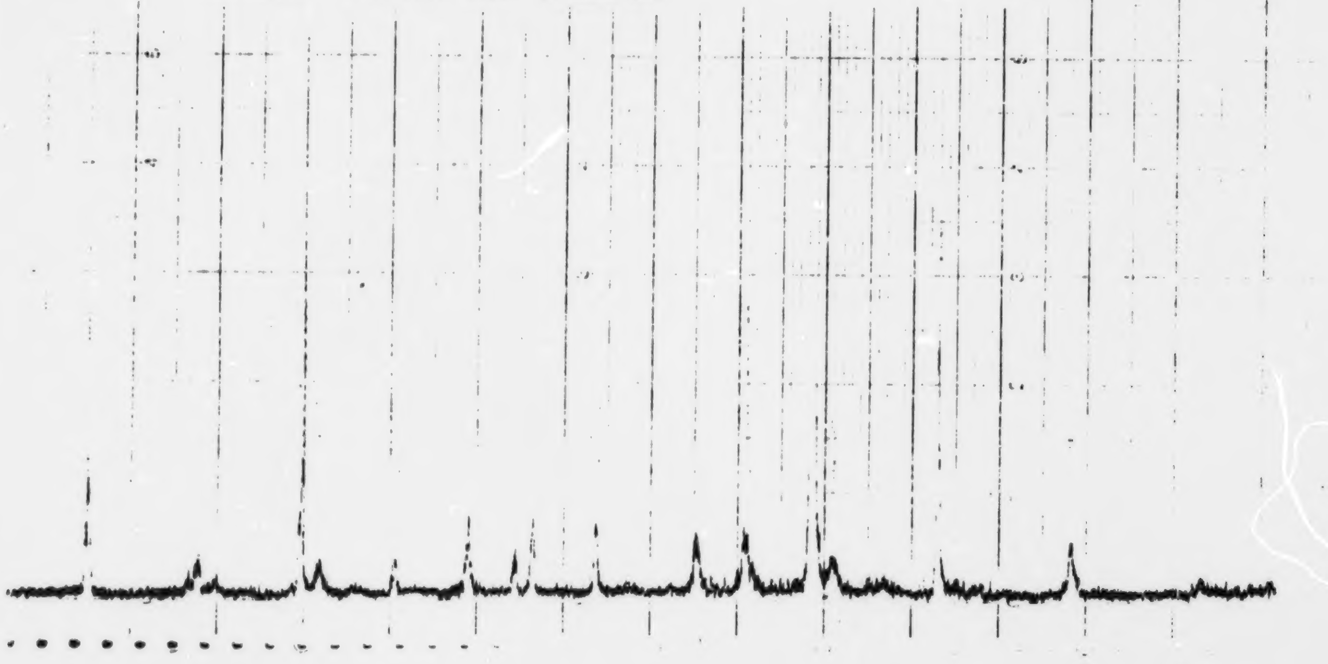
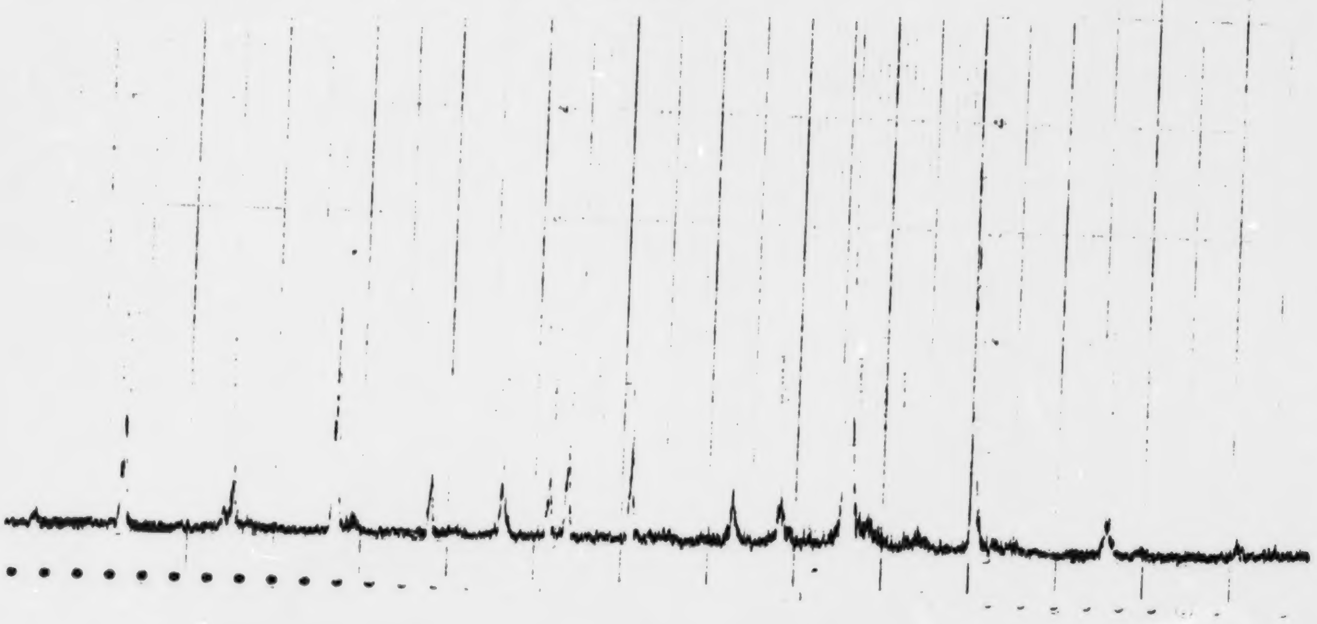
  50.220  1.8166     258
  50.351  1.8122     122
  60.056  1.5405     204
  60.202  1.5371     122


    65.500    1.4250
A5254+A5255    11-04-1984  11.17  PROGRAM 214
```



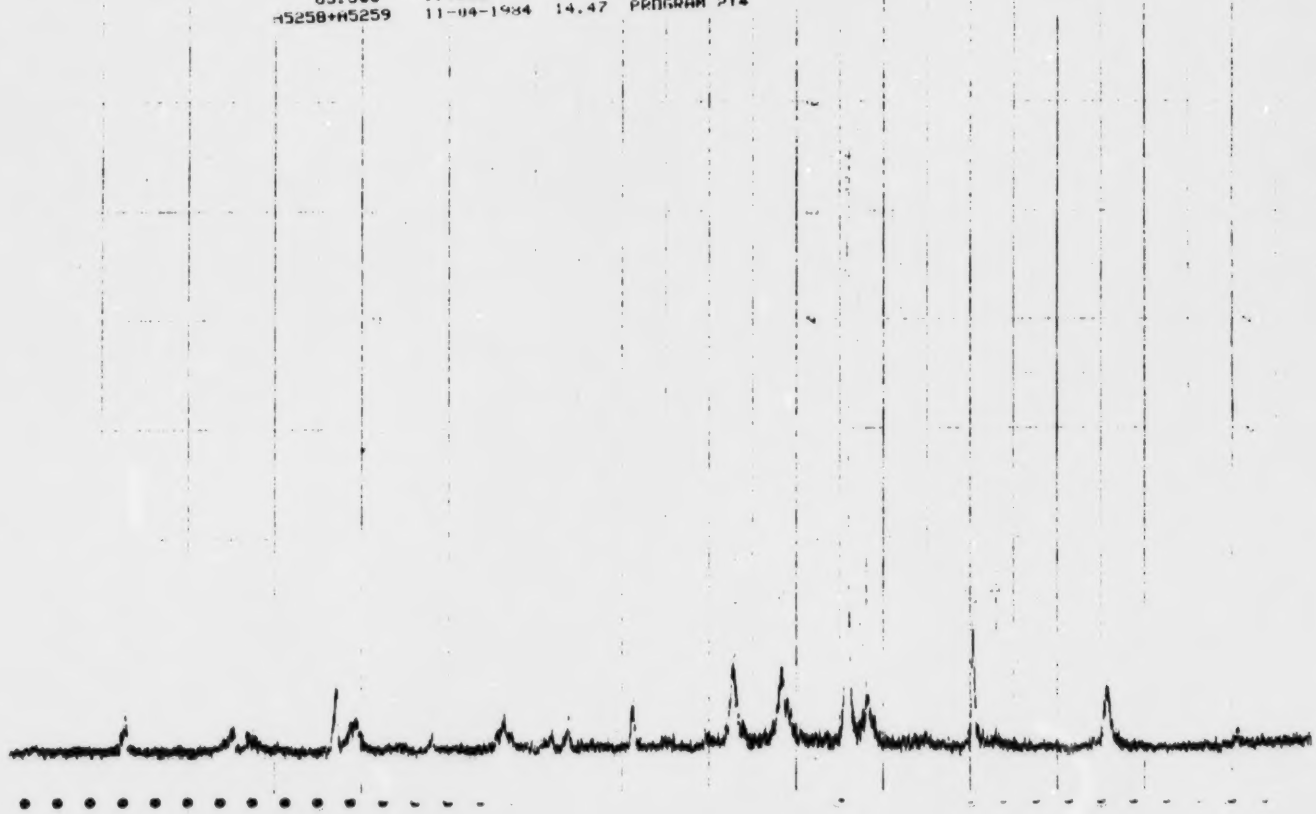
```
C=ID'A5256+A5257
C=1
A5256+A5257   11-04-1984  12.55  PROGRAM 214
     5.500   16.0677
 14.729  6.0140      74
 14.859  5.9617      80
 20.947  4.2407     556
 24.116  3.6903      42
 25.267  3.5246      30
 26.163  3.4060      64
 26.730  3.3350    2824
 29.771  3.0009     102
 32.016  2.7954     104
 36.620  2.4539     134
 38.189  2.3566      28
 39.546  2.2788     174
 40.379  2.2337     122
 42.543  2.1249     150
 45.872  1.9782     110
 50.223  1.8165     432
 50.352  1.8122     184
 54.951  1.6709     126
 60.024  1.5412     182
 60.197  1.5372     120

     65.500    1.4250
A5256+A5257   11-04-1984  13.16  PROGRAM 214
```



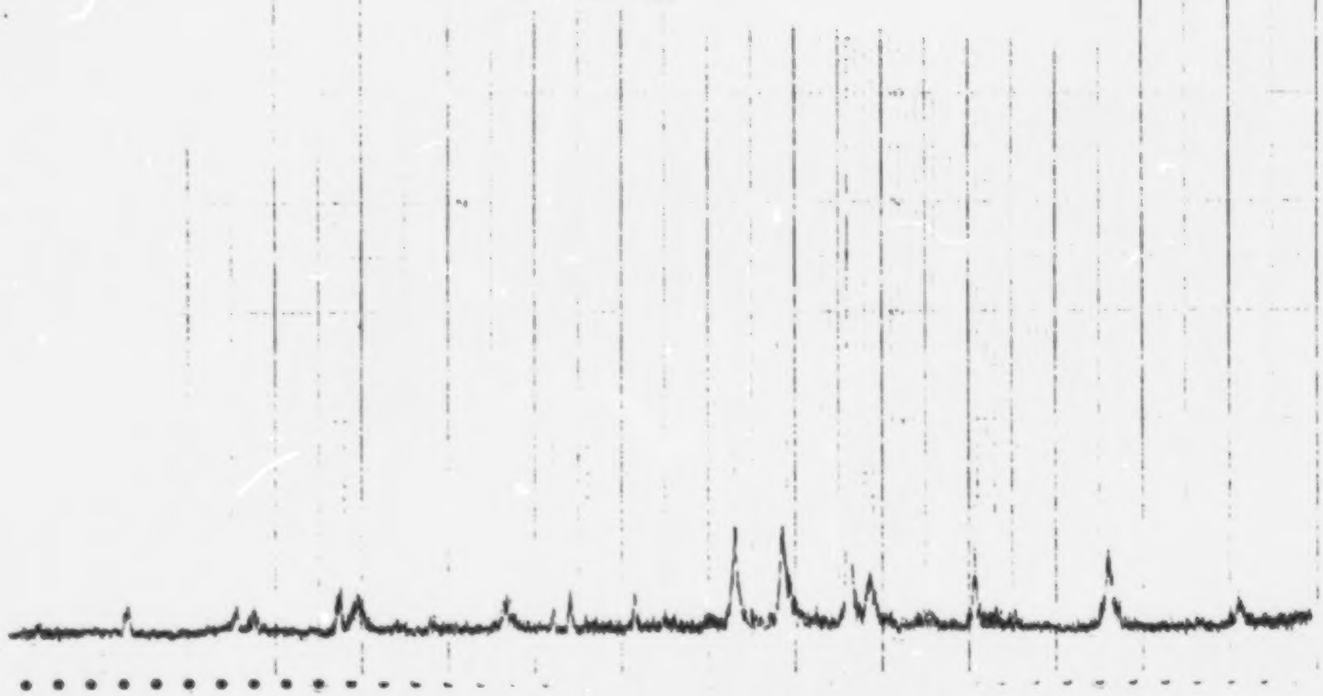
```
=IDIH5258+H5259
=:
H5258+H5259   11-04-1984  14.26  PROGRAM 214
     5.500   16.0677
  19.938  4.4531     40
  20.991  4.2320    182
  25.859  3.4454    120
  26.761  3.3312    914
  29.752  3.0027    120
  32.005  2.7963    124
  36.656  2.4515     78
  39.581  2.2768     56
  45.888  1.9775     36
  50.229  1.8163    112
  60.048  1.5407     84

     65.500    1.4250
H5258+H5259   11-04-1984  14.47  PROGRAM 214
```



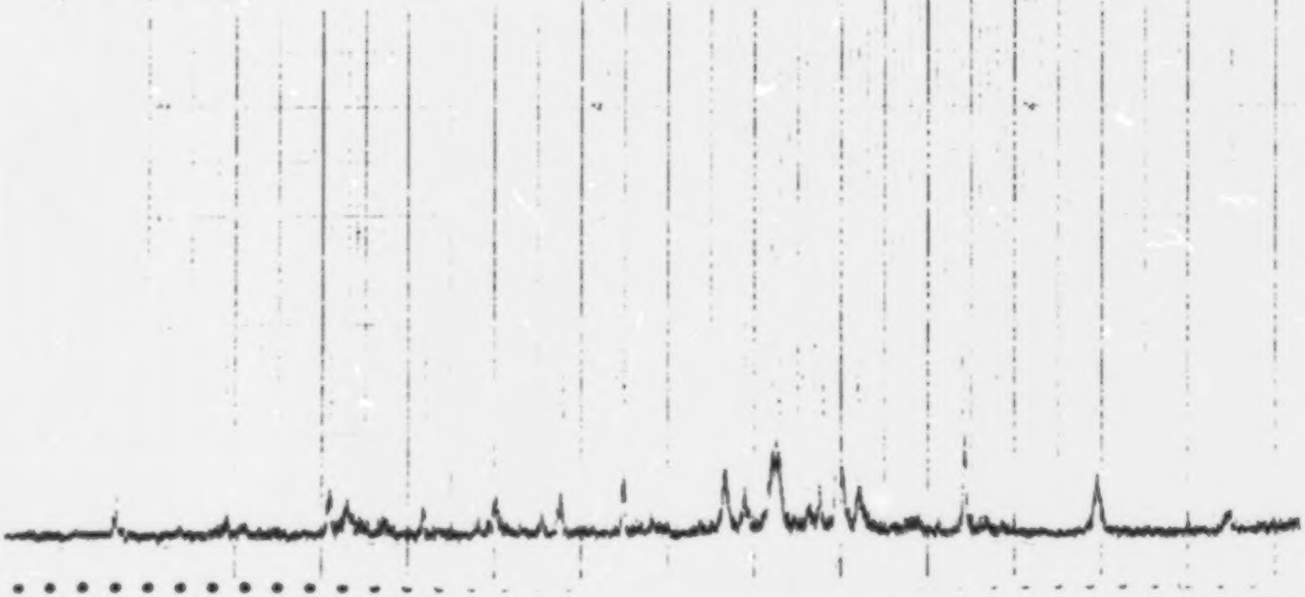
```
C=IDTA5260+A5261
=1
A5260+A5261     11-04-1984   15.35   PROGRAM 214
      5.500   16.0677
  8.893   9.9430      80
 14.813   5.9801     158
 19.110   4.6442      40
 20.010   4.4372      50
 20.967   4.2369     168 .
 25.772   3.4567     104
 26.745   3.3332     740 .
 29.470   3.0309      96
 29.795   2.9985     182
 31.973   2.7991     154 .
 36.644   2.4523      68 .
 38.857   2.3176      34
 40.365   2.2344      56 .
 50.199   1.8173      86 .
 54.970   1.6704      66 .

    65.500      1.4250
A5260+A5261     11-04-1984   15.55   PROGRAM 214
```



```
C=IDTA5262+A5263
C=1
A5262+A5263    12-04-1984   09.22   PROGRAM 214
     5.500    16.0677
 14.826  5.9751     100
 20.977  4.2349     166
 25.846  3.4471      46
 26.759  3.3315     983
 27.601  3.2317      72
 28.545  3.1270      53
 29.610  3.0169     156
 29.425  3.0354     140
 31.088  2.8767      74
 32.032  2.7941     102
 36.654  2.4517     106
 39.56.  2.2779      85
 39.670  2.2715      56
 40.411  2.2320      46
 42.294  2.1369      46
 42.658  2.1195      76
 45.904  1.9759      46
 50.244  1.8158      86
 54.952  1.6707      46
 60.043  1.5408      83

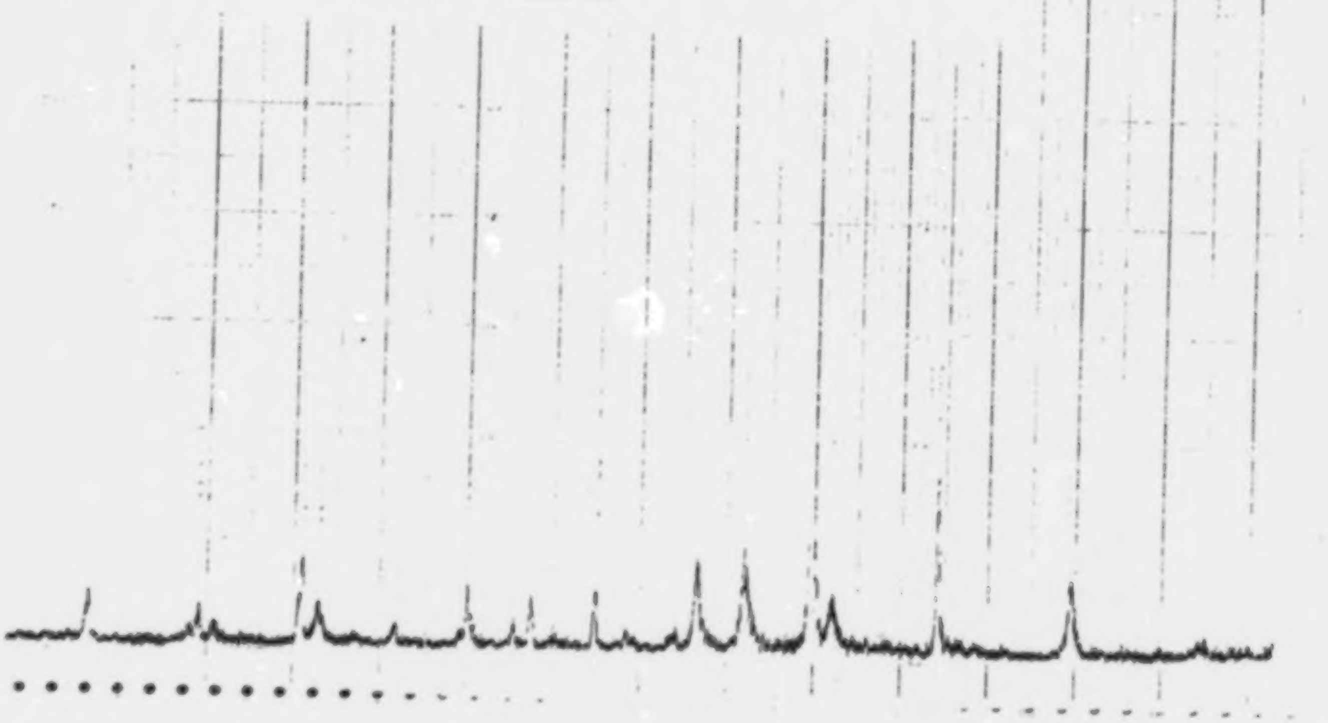
     65.500     1.4250
 A5262+A5263    12-04-1984   09.42   PROGRAM 214
```



```
..3TA5264+A5265

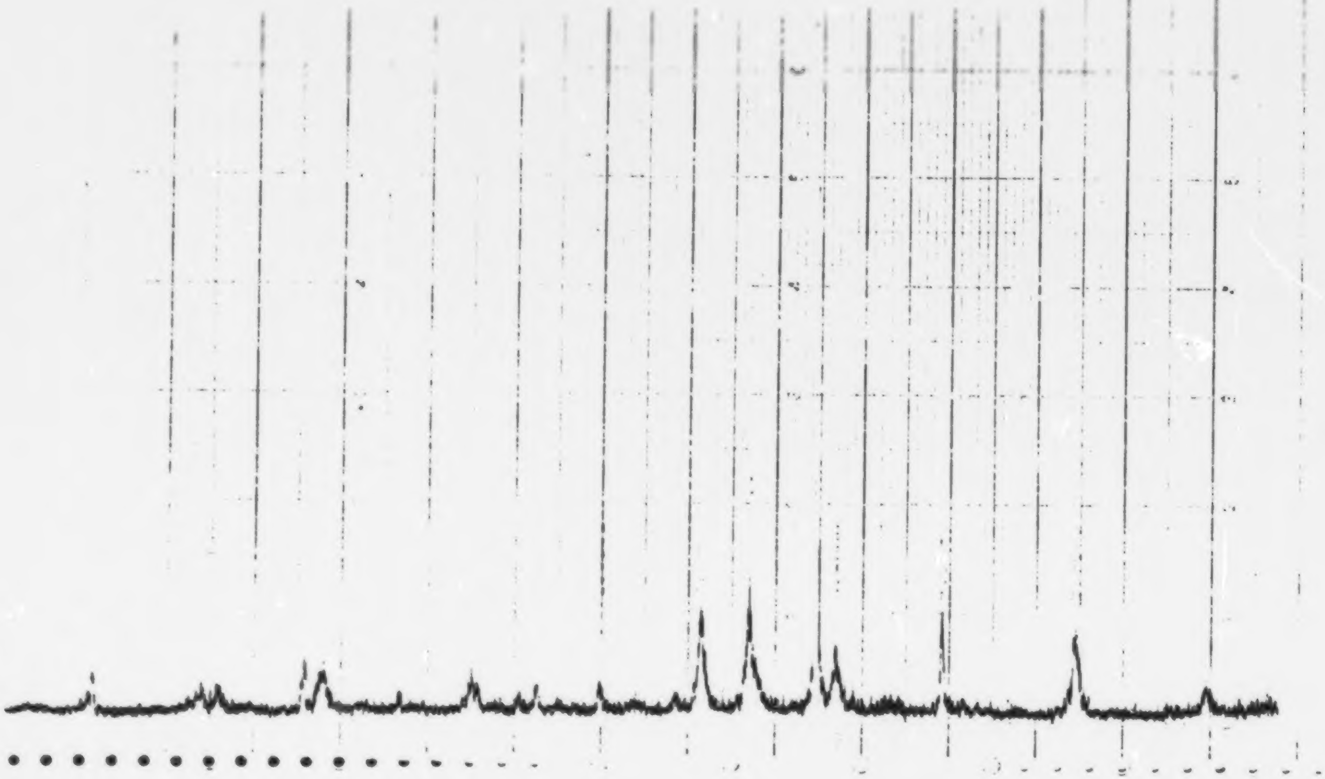
A5264+A5265   12-04-1984  10.56  PROGRAM 214
     5.500   16.0677
 14.785  5.9915    120
 20.985  4.2332    346 .
 26.764  3.3300   1530 .
 28.817  3.0980    116
 29.839  2.9942    164
 32.022  2.7949    150 .
 36.667  2.4500    128 .
 39.610  2.2752     94 .
 40.407  2.2322     33 .
 42.566  2.1239    116 .
 49.494  1.8416     82
 50.237  1.8161    176 .
 55.002  1.6695     59
 60.035  1.5410     98 .

    65.500    1.4250
A5264+A5265   12-04-1984  11.17  PROGRAM 214
```



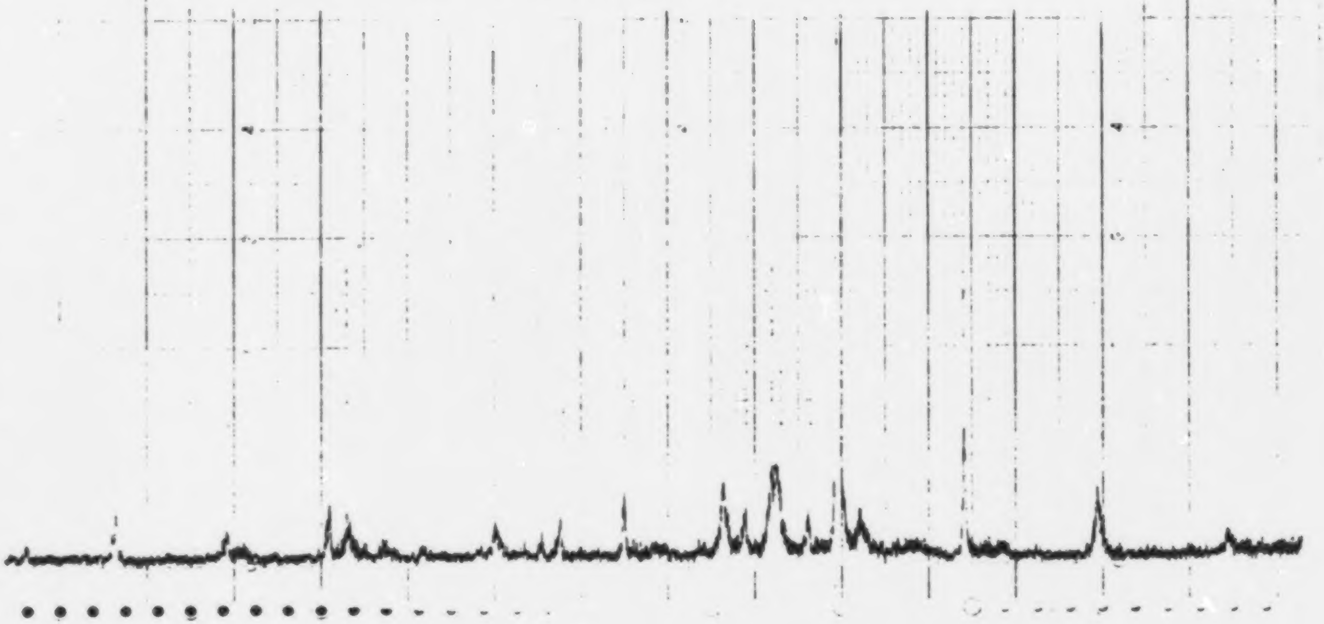
```
C+1[illegible]A5266+A5267 1+
C=1
A5266+A5267    12-04-1984  12.37  PROGRAM 214
      5.500    16.0677
    6.464 13.6737      44
   14.795  5.9876     160
   20.955  4.2392     182
   25.540  3.4866     110
   26.742  3.3336     960
   29.795  2.9965     242
   32.001  2.7967     182
   36.661  2.4512      62
   39.545  2.2788      66
   50.187  1.8178      98
   54.565  1.6818      48
   60.035  1.5418      98

     65.500    1.4250
A5266+A5267    12-04-1984  12.50  PROGRAM 214
```



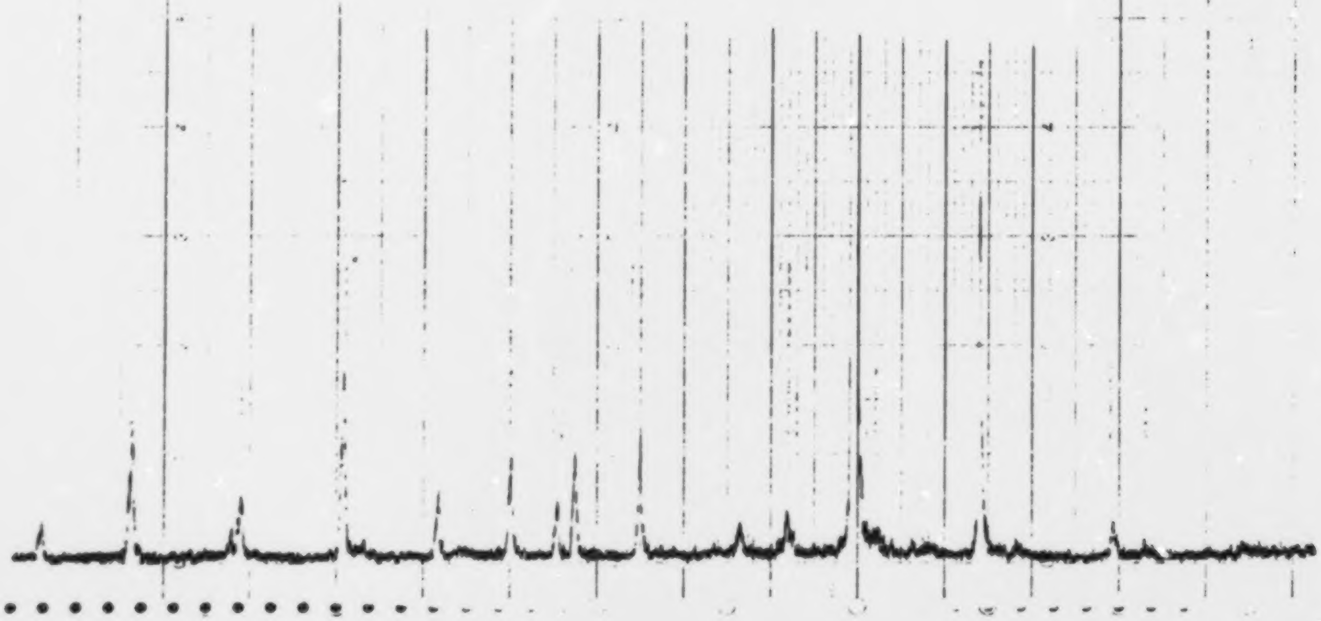
```
=IDTA5268+A5269
C=1
A5268+A5269    12-04-1984  14.09  PROGRAM 214
     5.500   16.0677
  14.550  6.0876       62
  14.833  5.9721      122
  20.951  4.2400      224
  26.741  3.3336     1074
  28.084  3.1772       76
  29.447  3.0331      130
  29.802  2.9978      174
  31.048  2.8803       78
  32.004  2.7965      128
  36.219  2.4801       42
  36.668  2.4507      102
  39.542  2.2790       66
  40.396  2.2328       68
  49.345  1.8468       68
  49.479  1.8421       59
  50.226  1.8164       98
  50.362  1.8119       58
  54.940  1.6712       68
  60.052  1.5406       92
  60.209  1.5369       58

     65.500    1.4250
A5268+A5269    12-04-1984  14.29  PROGRAM 214
```



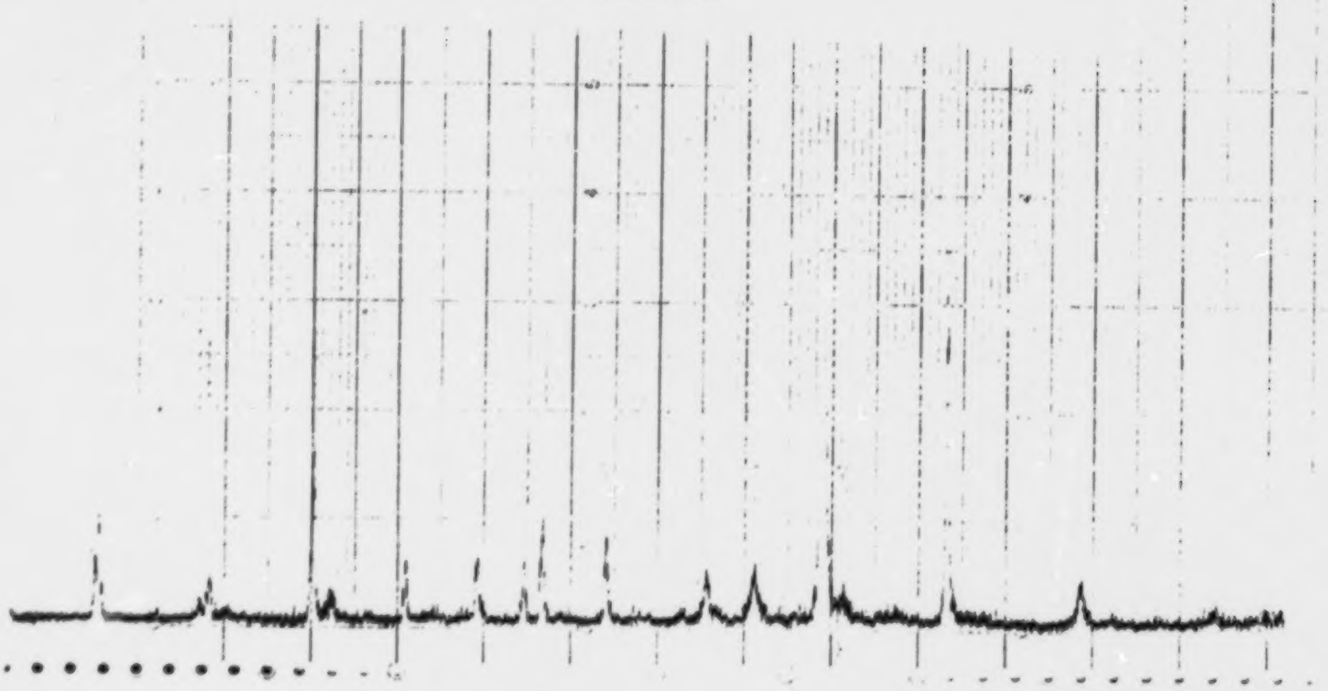
```
  IDTMA5270+A5271
A5270+A5271    12-04-1984  15.50  PROGRAM 214
      5.500   16.0677
   13.439   6.5935      40
   14.311   5.9809      70
   20.954   4.2394     634
   25.817   3.4508      74
   26.745   3.3332    3658
   29.524   3.0254      46
   29.821   2.9960      94
   36.627   2.4534     222
   39.569   2.2775     190
   40.392   2.2330     112
   42.523   2.1259     192 )
   42.601   2.1222     118 )
   45.877   1.9780     144
   50.237   1.8160     333 )
   50.324   1.8131     204 )
   54.966   1.6705     118
   55.395   1.6586      66
   60.034   1.5410     204
   60.177   1.5377     110
   64.121   1.4523      64

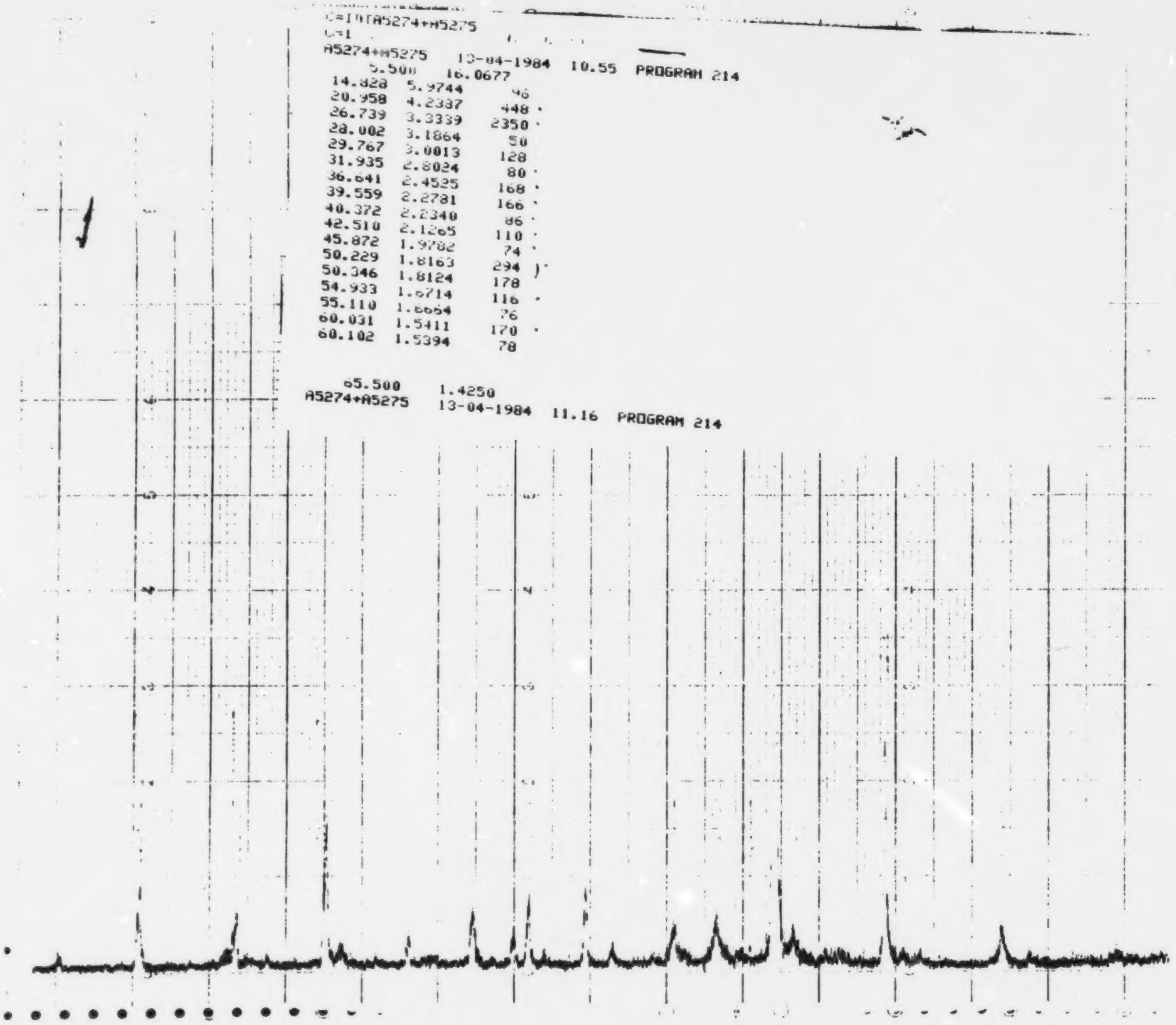
     65.500     1.4250
A5270+A5271     12-04-1984  16.11  PROGRAM 214
```



```
C=IBTA5272+A5273   I.I
C-1
A5272+A5273    13-04-1984   09.23  PROGRAM 214
     5.500   16.0677
 20.968  4.2367     524 '
 25.766  3.4576      84
 26.754  3.3321    2328  .
 29.776  3.0004     122
 36.662  2.4511     158 .
 39.500  2.2769     194 .
 40.404  2.2324     122 .
 42.548  2.1247     136 .
 42.648  2.1199      94
 45.914  1.9765     116 .
 50.225  1.8165     306 .
 54.972  1.6703      82 .
 55.127  1.6660      64
 60.057  1.5405     172 .
 60.215  1.5368      93
 64.131  1.4521      48 .

     65.500    1.4250
A5272+A5273    13-04-1984   09.43  PROGRAM 214
```



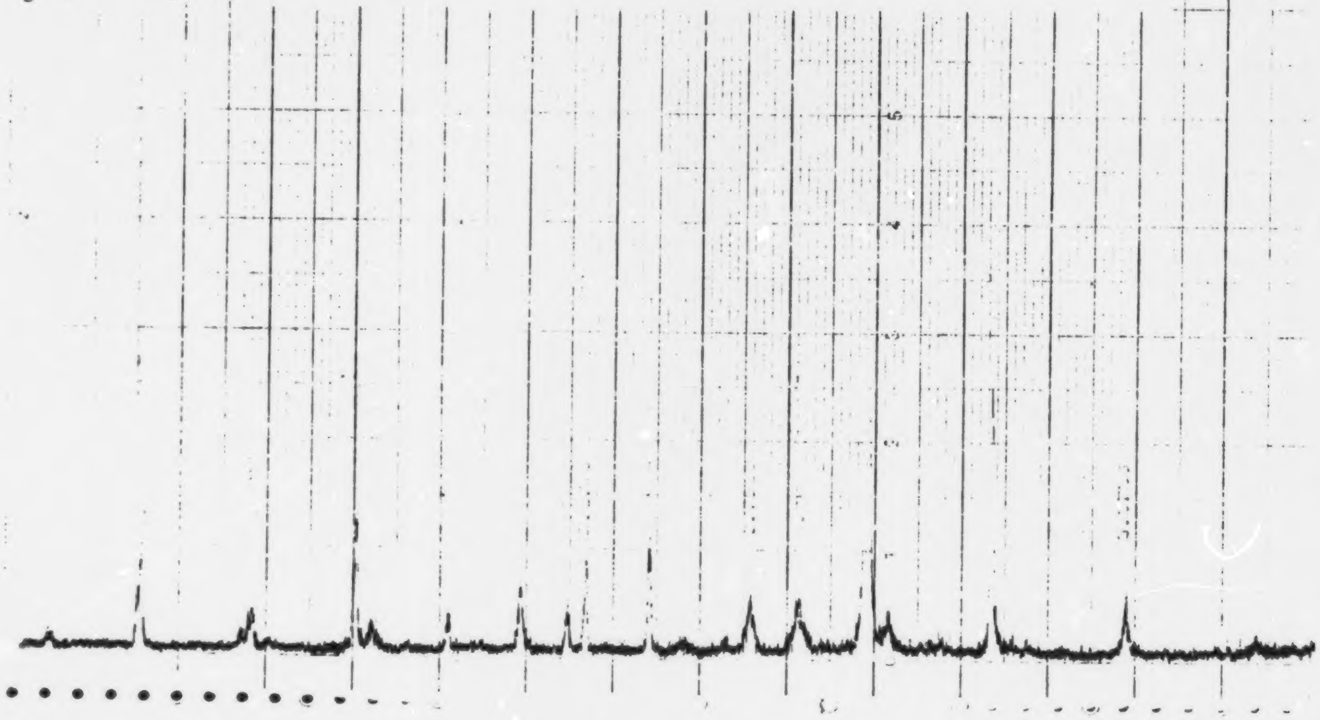


```
C=I0TA5274+A5275
C=1
A5274+A5275    13-04-1984  10.55  PROGRAM 214
      5.500   16.0677
  14.828  5.9744      46
  20.958  4.2337     448
  26.739  3.3339    2350
  28.002  3.1864      50
  29.767  3.0013     128
  31.935  2.8024      80
  36.641  2.4525     168
  39.559  2.2781     166
  40.372  2.2340      86
  42.510  2.1265     110
  45.872  1.9782      74
  50.229  1.8163     294
  50.346  1.8124     178
  54.933  1.6714     116
  55.110  1.6664      76
  60.031  1.5411     170
  60.102  1.5394      78

     65.500     1.4250
A5274+A5275    13-04-1984  11.16  PROGRAM 214
```

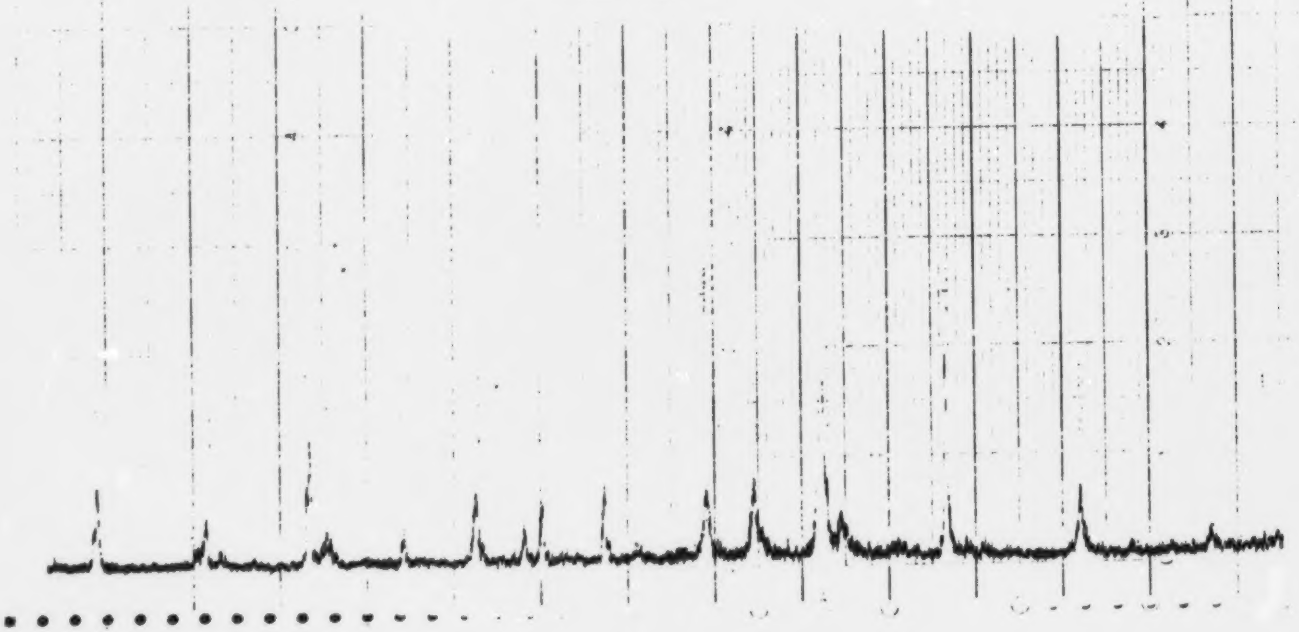
```
C=IDTA5276+A5277
C=1
A5276+A5277    13-04-1984  12.33  PROGRAM 214
     5.500   16.0677
 14.826  5.9750      90
 20.952  4.2398     448
 26.742  3.3335    2262
 29.718  3.0061     108
 29.836  2.9945     100
 31.999  2.7969     100
 36.634  2.4529     184
 39.562  2.2779     172
 40.387  2.2333      80
 42.560  2.1241     116
 45.915  1.9764      68
 50.223  1.8165     248
 54.952  1.6709      64
 60.035  1.5410     160
 60.189  1.5374      94


    65.500    1.4250
A5276+A5277    13-04-1984  12.53  PROGRAM 214
```



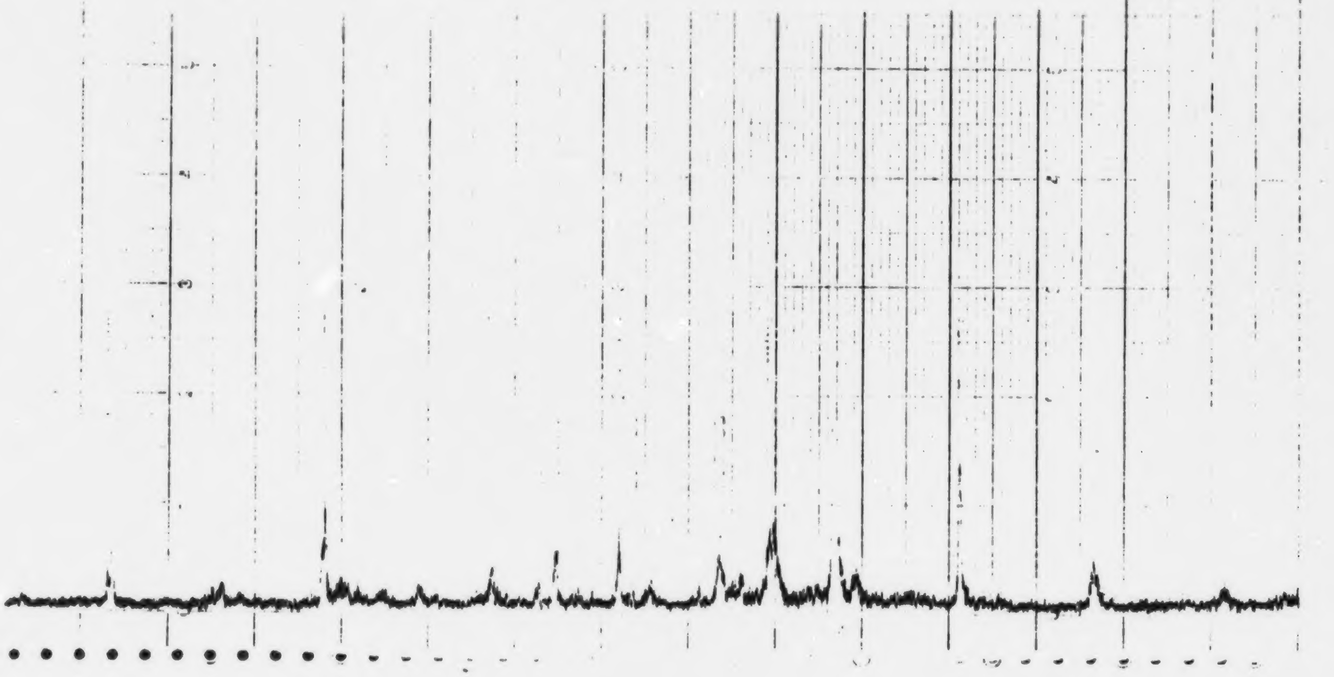
```
  IDfA5278+A5279 LM
C=1
A5278+A5279    13-04-1984  14.11  PROGRAM 214
     5.500   16.0677
  6.320 13.9849       44
 14.787  5.9905      114
 20.944  4.2413      352 ·
 26.447  3.3700      126
 26.734  3.3345     2016 ·
 29.731  3.0048      140
 31.467  2.8429       50
 31.911  2.8044      114 ·
 36.622  2.4538      150 ·
 39.549  2.2786      120 ·
 40.382  2.2335       72 ·
 42.539  2.1251      136 ·
 45.876  1.9780       70 ·
 49.425  1.8440       69
 50.218  1.8167      260 )·
 50.347  1.8123      140
 54.956  1.6707       88 ·
 60.039  1.5409      144 ·

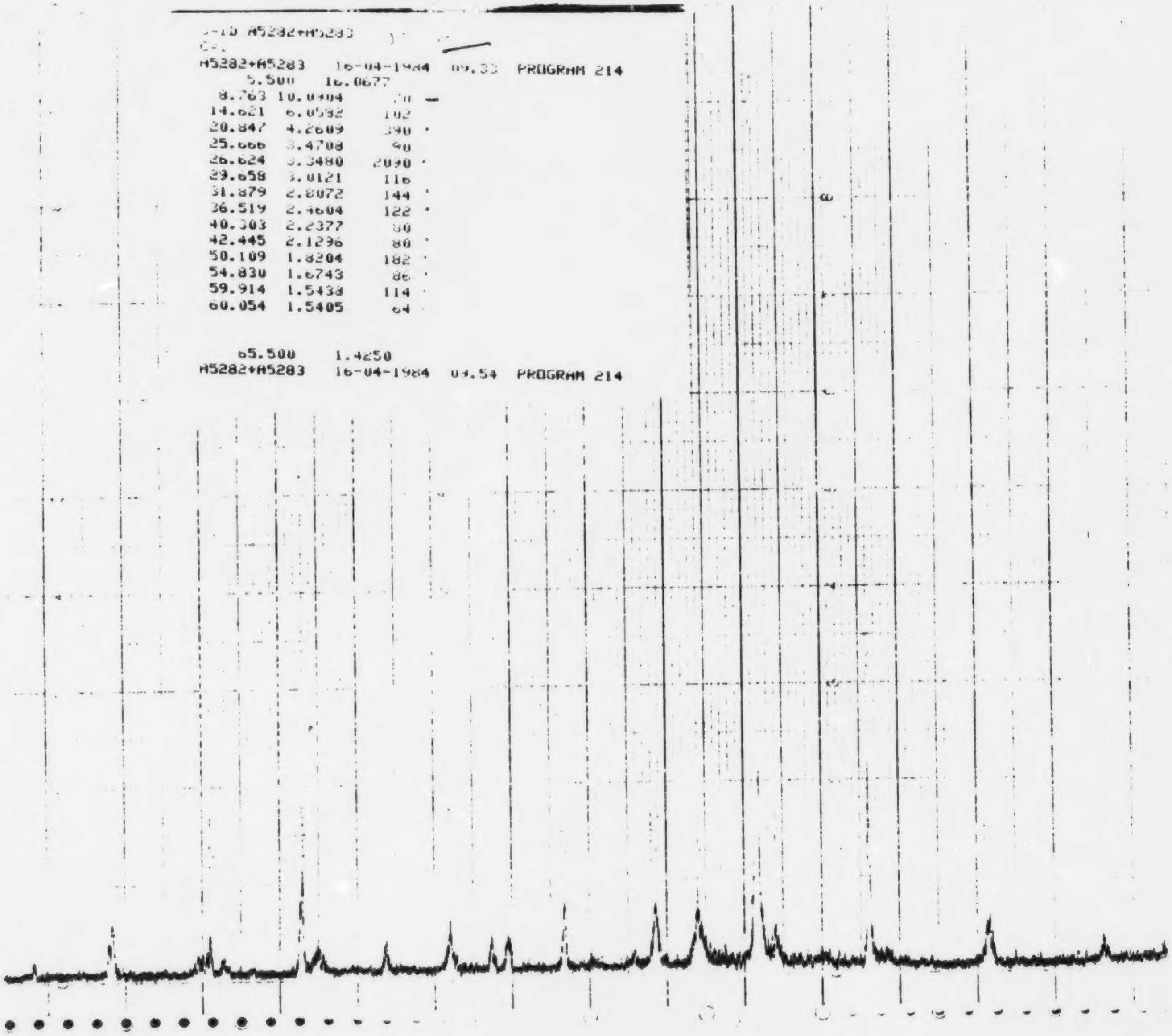
   65.500    1.4250
A5278+A5279    13-04-1984  14.32  PROGRAM 214
```



```
C=IDTA5280+A5281  E. [illegible]
C=1
A5280+A5281    13-04-1984  15.45  PROGRAM 214
      5.500   16.0677
 14.830  5.9734      90
 20.960  4.2332     252 ·
 26.747  3.3329    1232 ·
 29.613  3.0166     152
 29.778  3.0002     136
 31.980  2.7935     104 ·
 36.013  2.4933      36
 36.663  2.4511     136 ·
 39.540  2.2787     104 ·
 40.360  2.2343      52 ·
 41.895  2.1563      36
 42.545  2.1248      80 ·
 50.228  1.8164     180 ).
 50.353  1.8122     114
 60.038  1.5409     110 ·
 60.216  1.5368      76

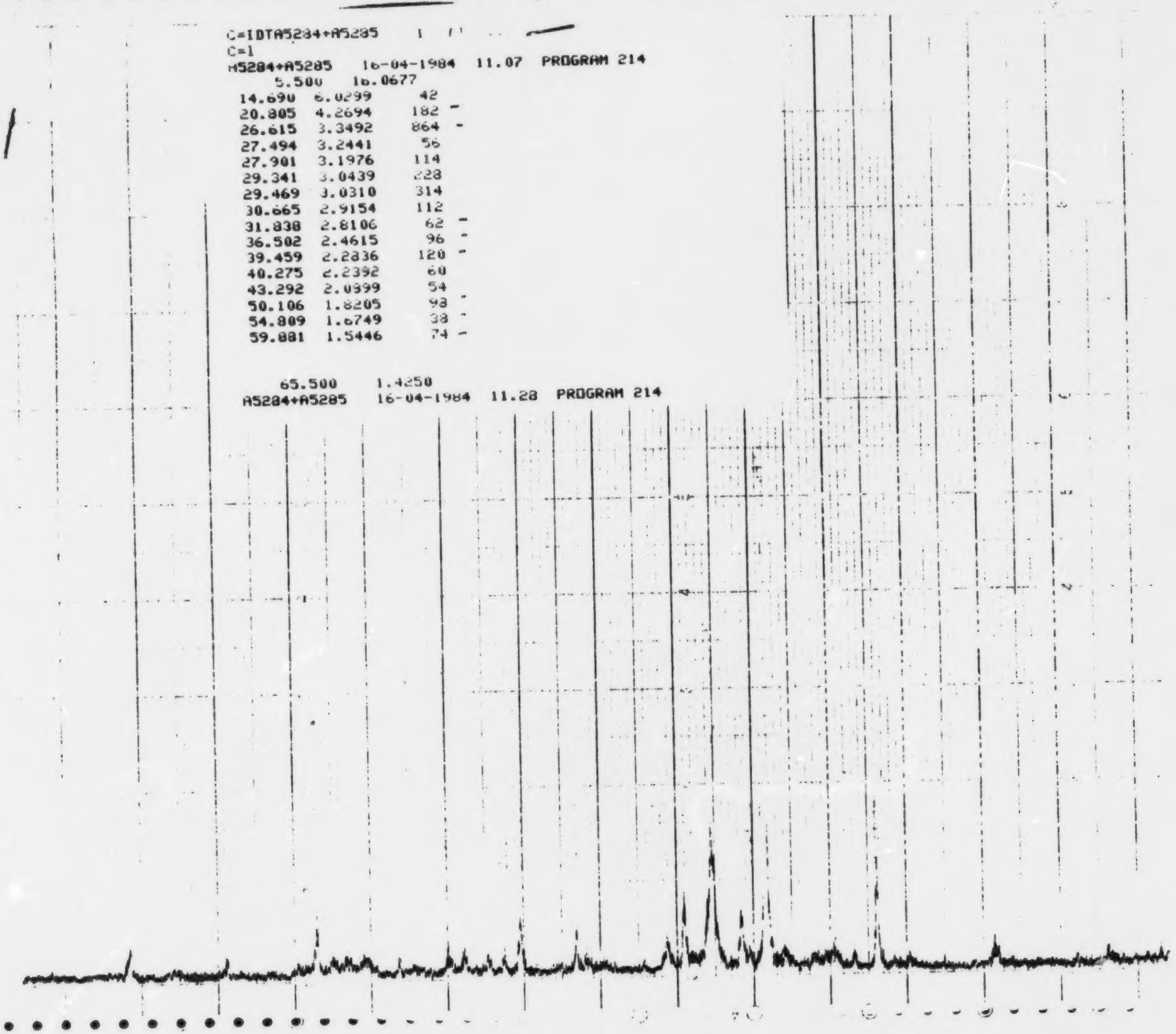

     65.500    1.4250
A5280+A5281    13-04-1984  16.05  PROGRAM 214
```





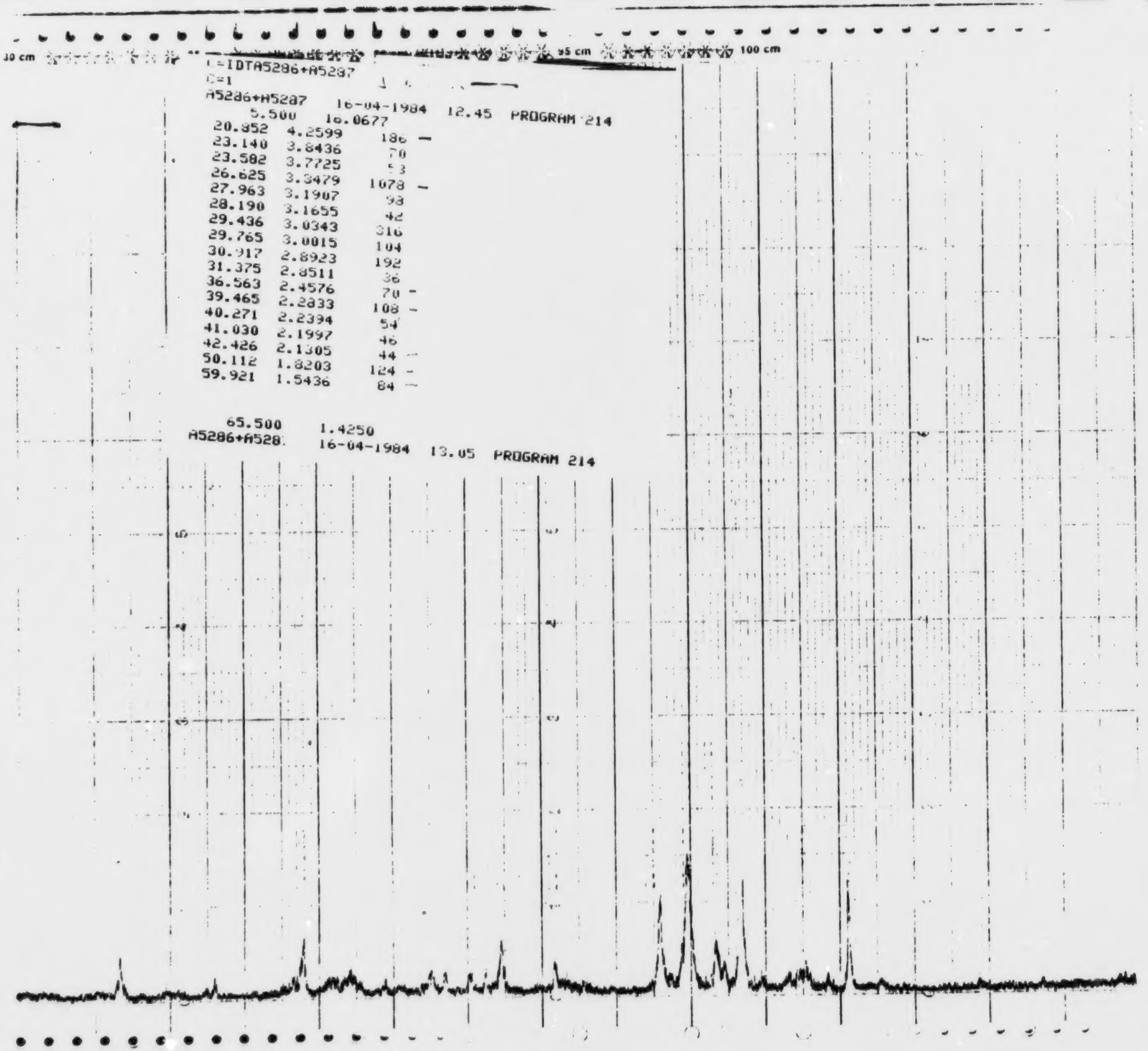
```
--1D A5282+A5283
C=.
A5282+A5283    16-04-1984   09.33   PROGRAM 214
     5.500   16.0677
   8.763 10.0404      [illegible] -
  14.621  6.0592      102
  20.847  4.2609      390 .
  25.666  3.4708       90
  26.624  3.3480     2090 .
  29.658  3.0121      116
  31.879  2.8072      144 .
  36.519  2.4604      122 .
  40.303  2.2377       80
  42.445  2.1296       80 .
  50.109  1.8204      182 .
  54.830  1.6743       86 .
  59.914  1.5438      114 .
  60.054  1.5405       64

     65.500    1.4250
A5282+A5283    16-04-1984   09.54   PROGRAM 214
```



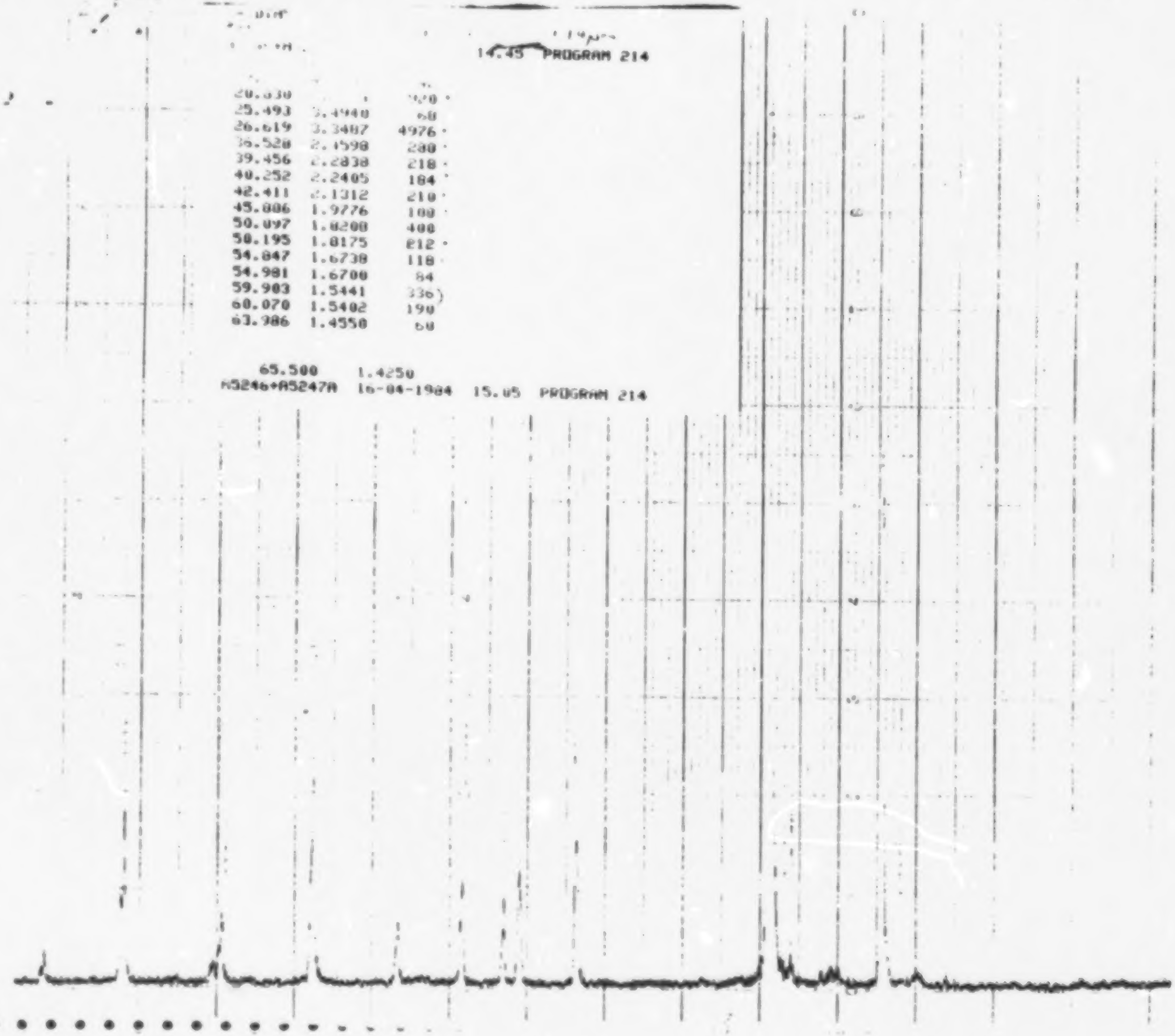
```
C=IDTA5284+A5285
C=1
A5284+A5285    16-04-1984  11.07  PROGRAM 214
     5.500   16.0677
 14.690  6.0299       42
 20.805  4.2694      182 -
 26.615  3.3492      864 -
 27.494  3.2441       56
 27.901  3.1976      114
 29.341  3.0439      228
 29.469  3.0310      314
 30.665  2.9154      112
 31.838  2.8106       62 -
 36.502  2.4615       96 -
 39.459  2.2836      120 -
 40.275  2.2392       60
 43.292  2.0399       54
 50.106  1.8205       98 -
 54.809  1.6749       38 -
 59.881  1.5446       74 -

     65.500     1.4250
 A5284+A5285    16-04-1984  11.28  PROGRAM 214
```



```
C=IDTA5286+A5287
C=1
A5286+A5287     16-04-1984   12.45   PROGRAM 214
     5.500    16.0677
  20.852   4.2599     186 —
  23.140   3.8436      70
  23.582   3.7725      53
  26.625   3.3479    1078 —
  27.963   3.1907      98
  28.190   3.1655      42
  29.436   3.0343     316
  29.765   3.0015     104
  30.917   2.8923     192
  31.375   2.8511      36
  36.563   2.4576      70 -
  39.465   2.2833     108 -
  40.271   2.2394      54
  41.030   2.1997      46
  42.426   2.1305      44 -
  50.112   1.8203     124 -
  59.921   1.5436      84 -

    65.500     1.4250
A5286+A528.     16-04-1984   13.05   PROGRAM 214
```



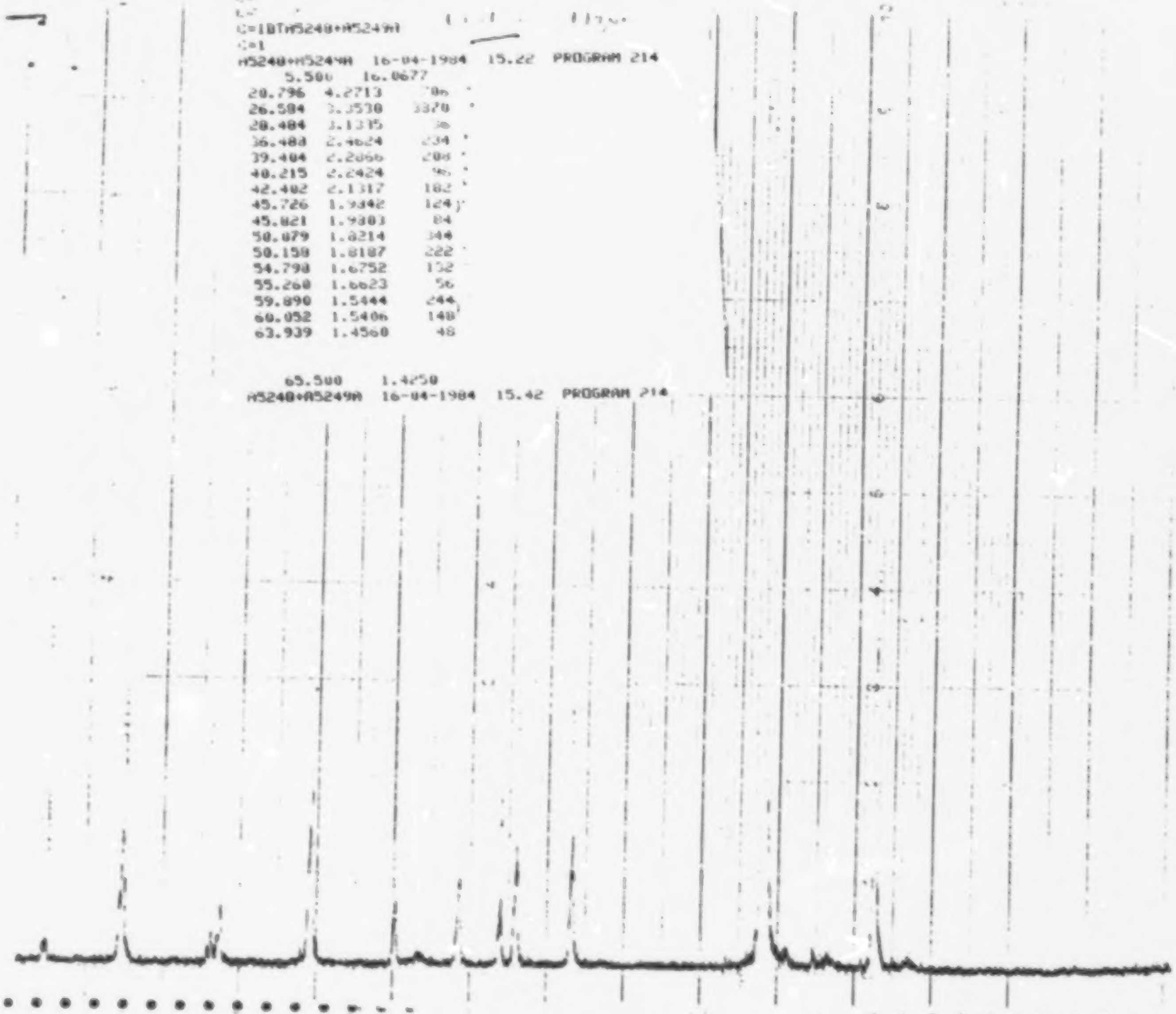
```
                                 14.45  PROGRAM 214

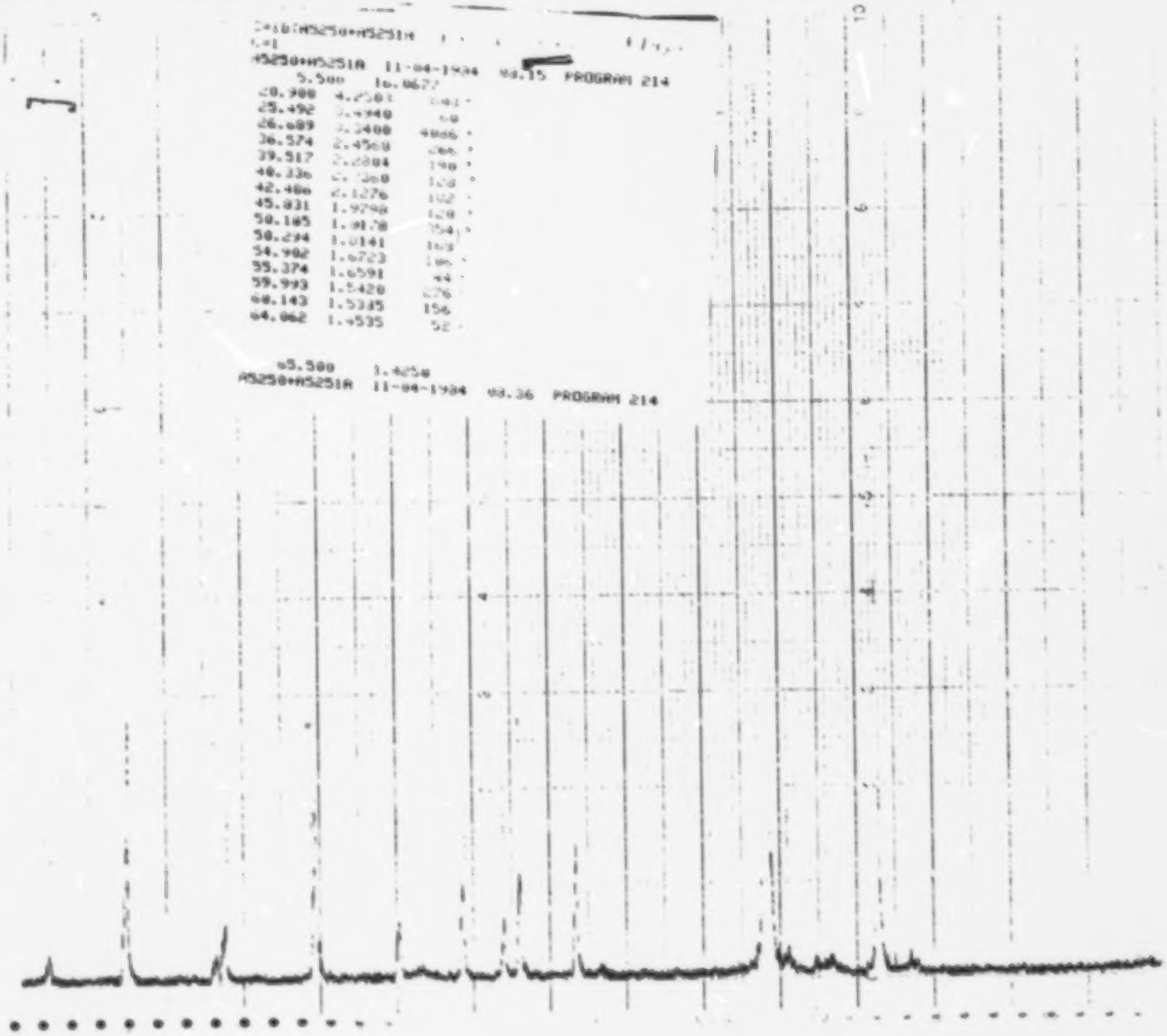
20.830    [illegible]   [illegible]
25.493    3.4940     60
26.619    3.3487   4976
36.520    2.4598    280
39.456    2.2838    218
40.252    2.2405    184
42.411    2.1312    210
45.806    1.9776    100
50.097    1.8200    400
50.195    1.8175    212
54.847    1.6730    118
54.981    1.6700     84
59.903    1.5441    336
60.070    1.5402    190
63.986    1.4550     60

    65.500    1.4250
A5246+A5247A  16-04-1984  15.05  PROGRAM 214
```

```
C=
C=
C=1BTA5248+A5249A
C=1
A5248+A5249A   16-04-1984   15.22   PROGRAM 214
      5.500    16.0677
  20.796   4.2713     706
  26.584   3.3530    3370
  28.484   3.1335      36
  36.488   2.4624     234
  39.404   2.2866     208
  40.215   2.2424      96
  42.402   2.1317     182
  45.726   1.9842     124
  45.821   1.9803      84
  50.079   1.8214     344
  50.158   1.8187     222
  54.798   1.6752     132
  55.268   1.6623      56
  59.890   1.5444     244
  60.052   1.5406     148
  63.939   1.4560      48

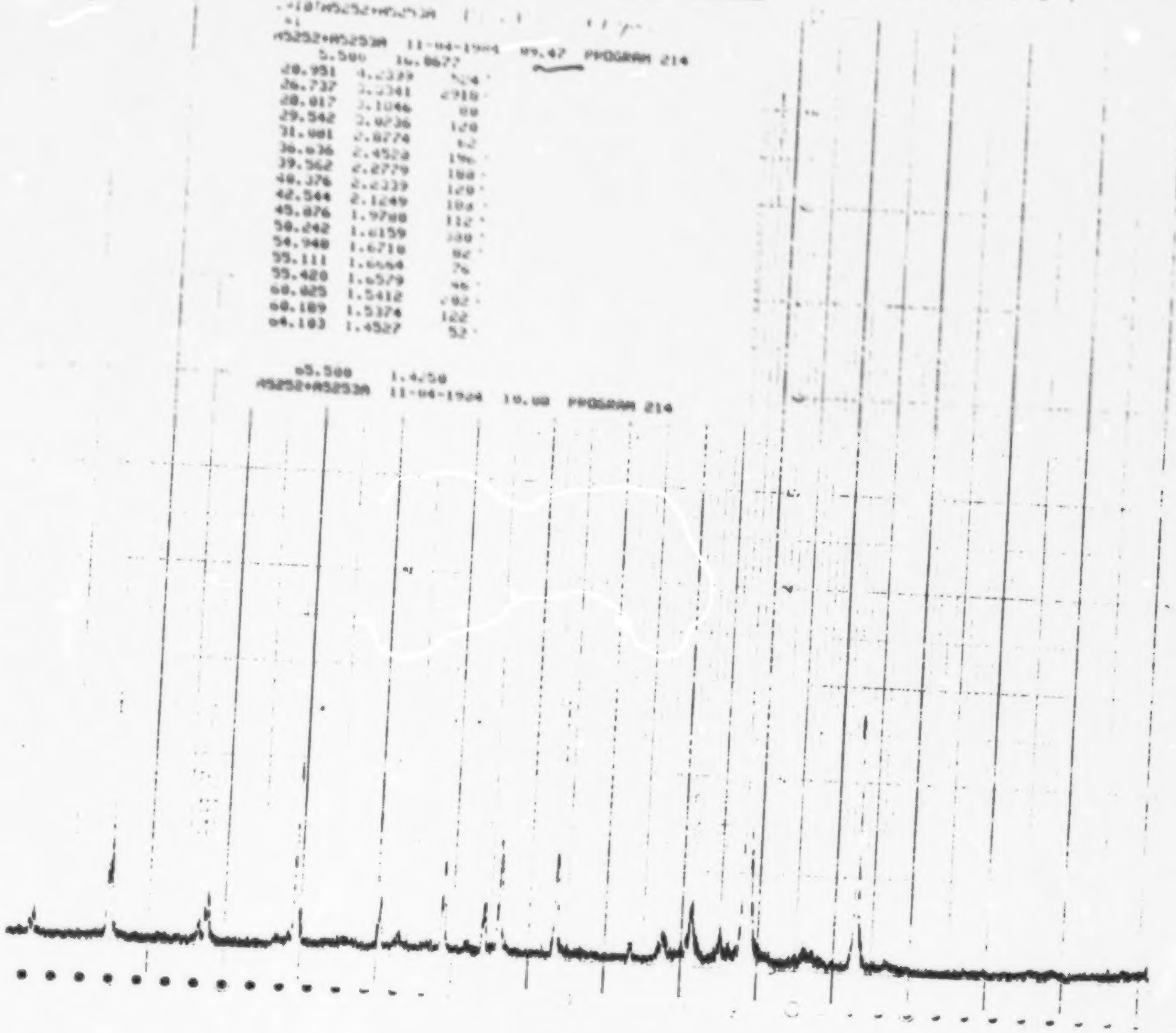
      65.500    1.4250
A5248+A5249A   16-04-1984   15.42   PROGRAM 214
```





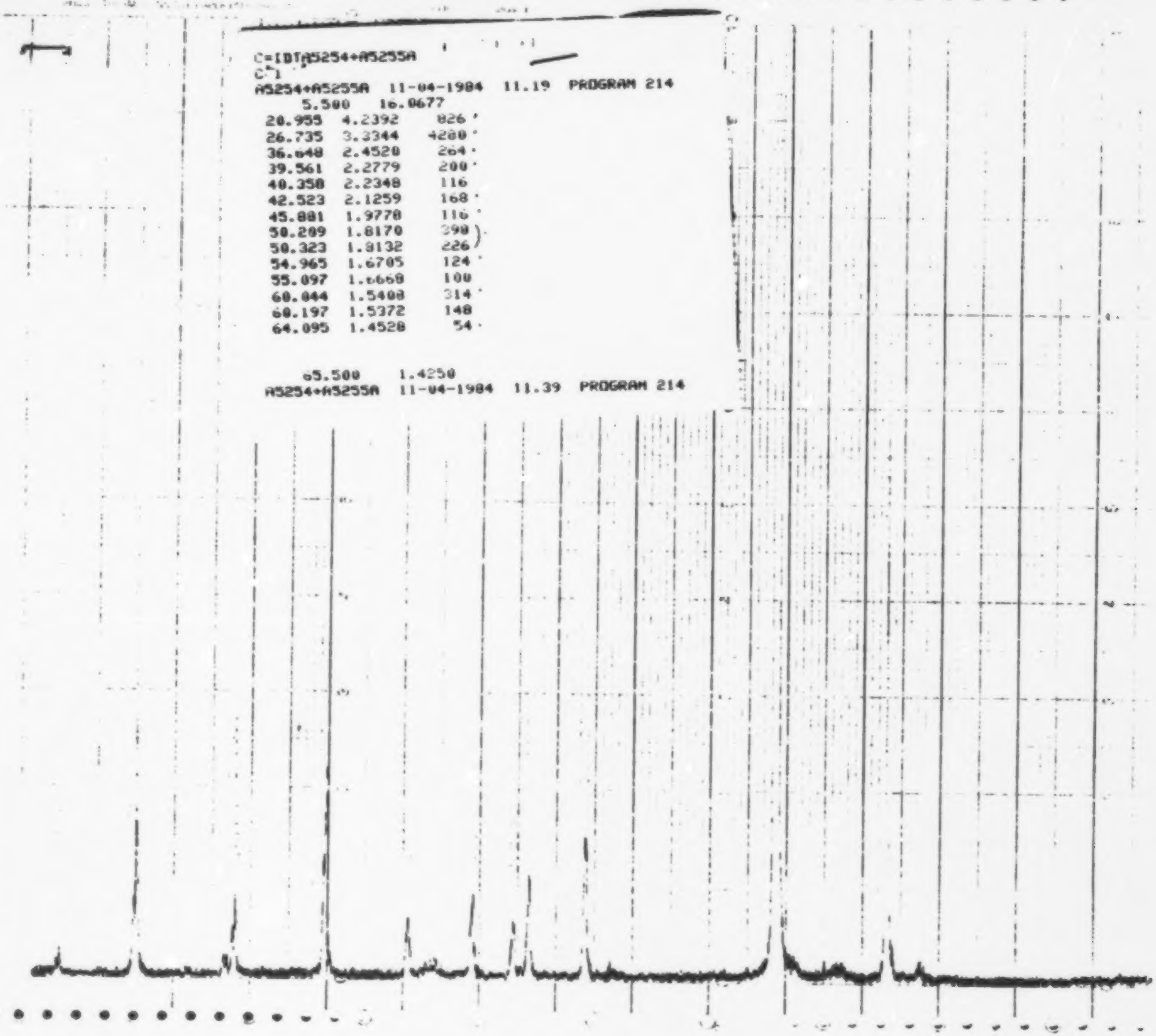
```
D+1b:A5250+A5251A
C:1
A5250+A5251A  11-04-1984  09.15  PROGRAM 214
     5.500   16.0677
  20.900   4.2503     843
  25.492   3.4940      68
  26.689   3.3400    4086
  36.574   2.4560     266
  39.517   2.2804     190
  40.336   2.2360     128
  42.480   2.1276     102
  45.831   1.9798     120
  50.165   1.8178     754
  50.294   1.8141     163
  54.902   1.6723     106
  55.374   1.6591      44
  59.993   1.5420     276
  60.143   1.5385     156
  64.062   1.4535      52

     65.500    1.4250
A5250+A5251A  11-04-1984  09.36  PROGRAM 214
```



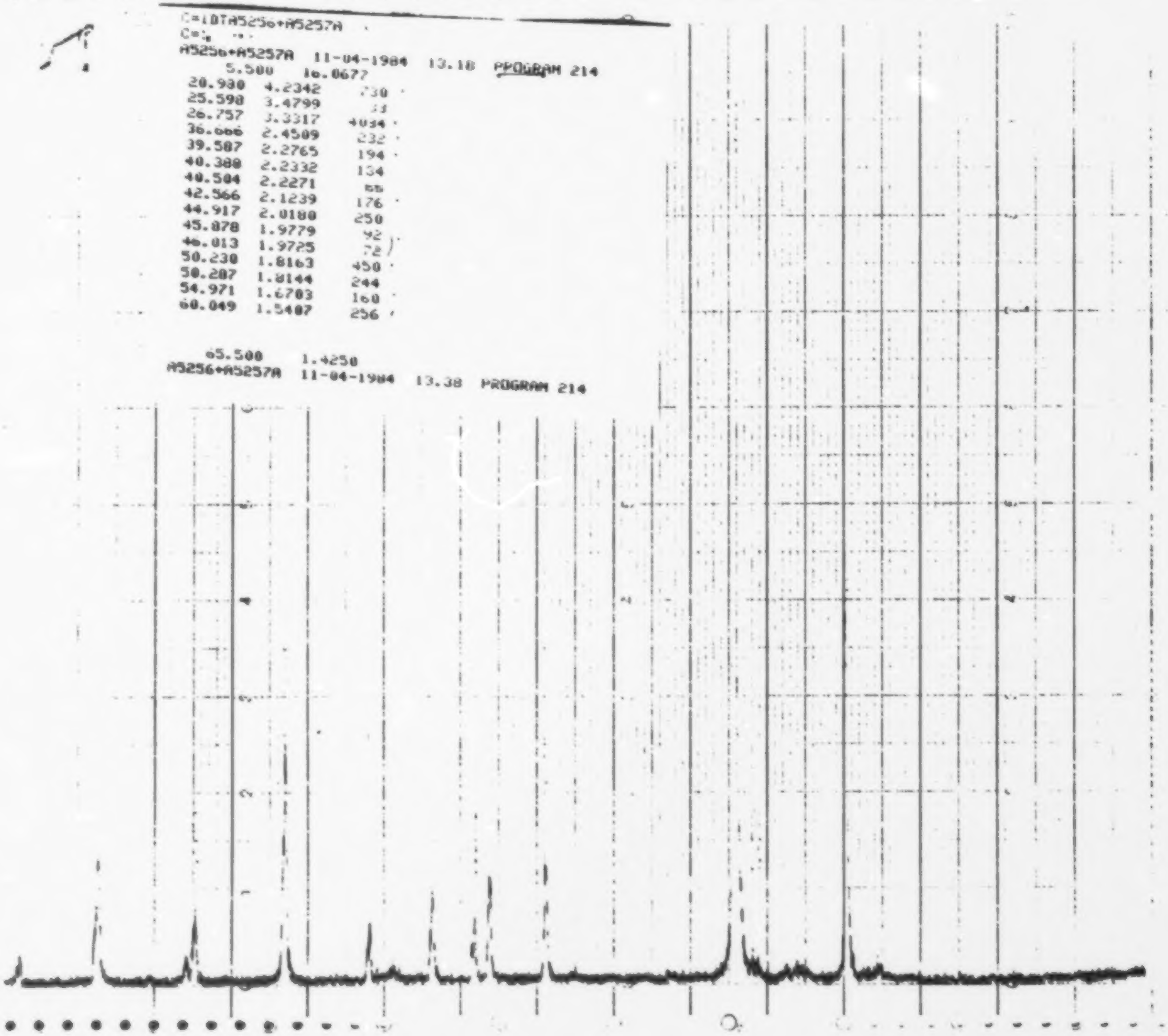
```
.*IDT*A5252+A5253A
*1
A5252+A5253A  11-04-1984  09.47  PROGRAM 214
     5.500   16.0677
  20.951  4.2339   524
  26.737  3.3341  2918
  28.017  3.1046    88
  29.542  3.0236   120
  31.001  2.8774    62
  36.636  2.4520   196
  39.562  2.2779   100
  40.376  2.2339   120
  42.544  2.1249   104
  45.076  1.9788   112
  50.242  1.8159   300
  54.940  1.6710    82
  55.111  1.6664    76
  55.420  1.6579    46
  60.025  1.5412   202
  60.189  1.5374   122
  64.103  1.4527    52

     65.500   1.4250
A5252+A5253A  11-04-1984  10.00  PROGRAM 214
```



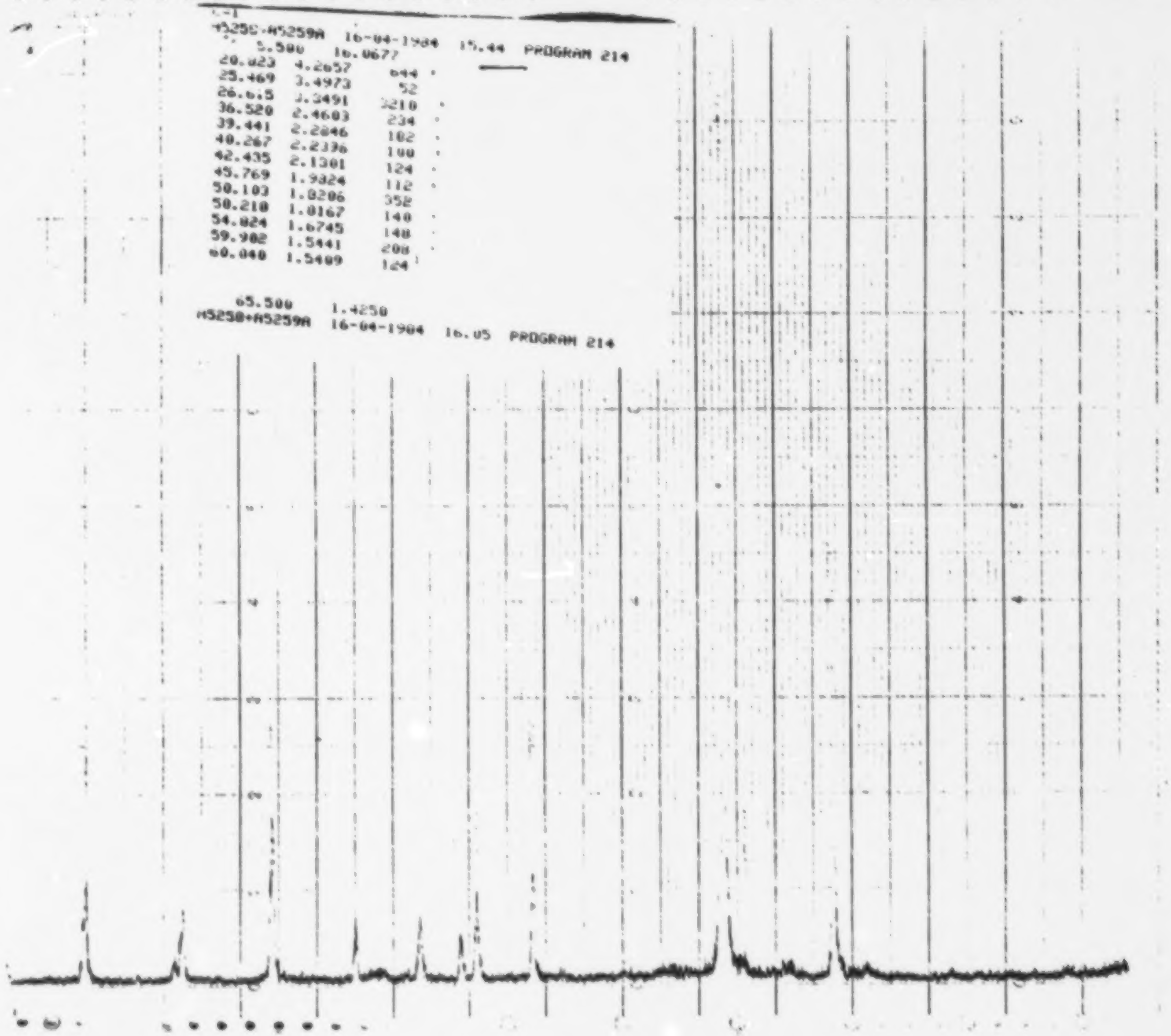
```
C=IDTA5254+A5255A
C^1
A5254+A5255A  11-04-1984  11.19  PROGRAM 214
      5.500   16.0677
 20.955  4.2392     826
 26.735  3.3344    4200
 36.648  2.4520     264
 39.561  2.2779     200
 40.350  2.2348     116
 42.523  2.1259     168
 45.881  1.9770     116
 50.209  1.8170     390
 50.323  1.8132     226
 54.965  1.6705     124
 55.097  1.6660     100
 60.044  1.5400     314
 60.197  1.5372     148
 64.095  1.4520      54

     65.500    1.4250
 A5254+A5255A  11-04-1984  11.39  PROGRAM 214
```



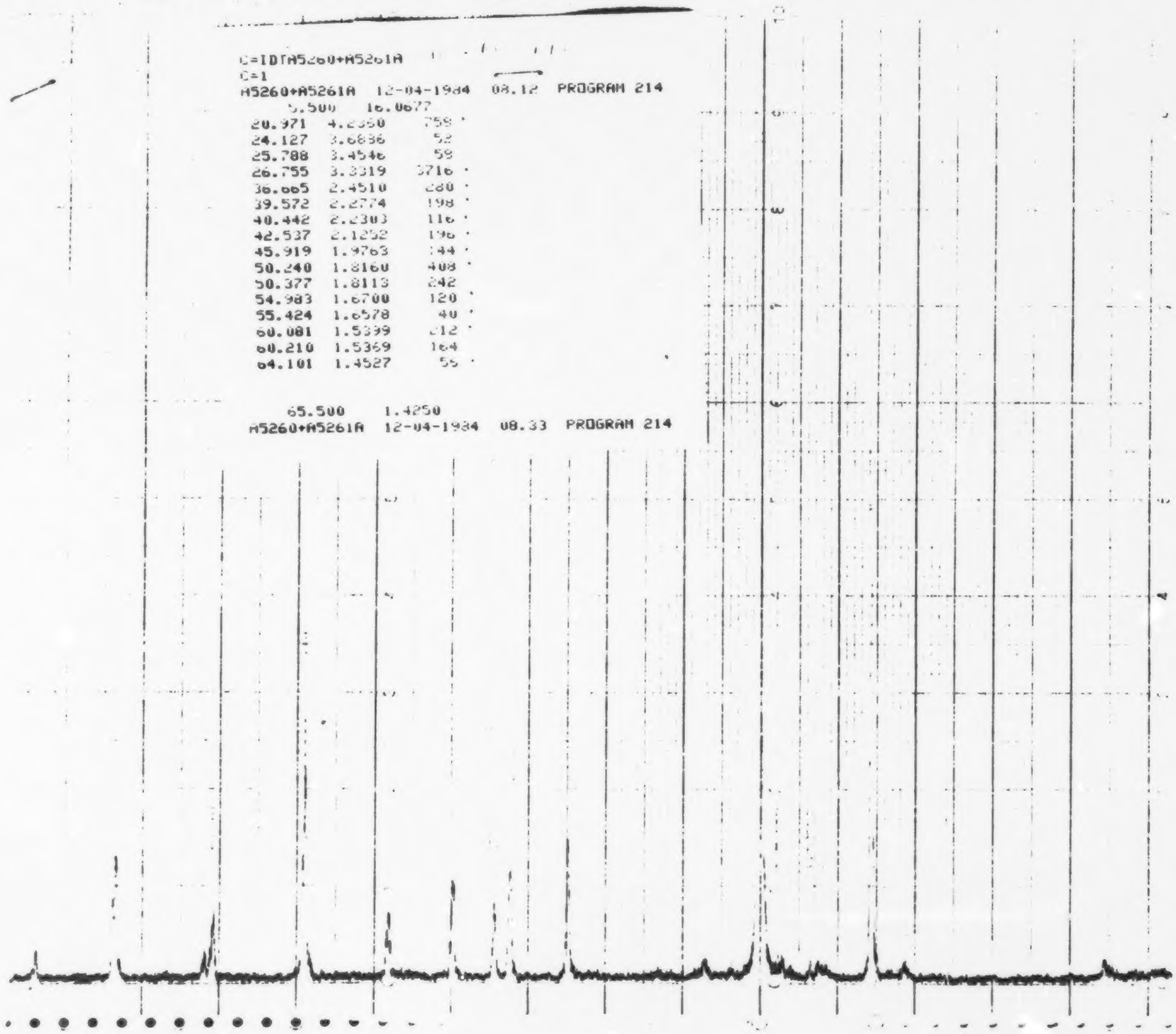
```
C=1DTA5256+A5257A
C=;  ..
A5256+A5257A  11-04-1984  13.18  PROGRAM 214
     5.500   16.0677
 20.930  4.2342     730
 25.590  3.4799      33
 26.757  3.3317    4034
 36.666  2.4509     232
 39.587  2.2765     194
 40.388  2.2332     134
 40.504  2.2271      66
 42.566  2.1239     176
 44.917  2.0180     250
 45.878  1.9779      92
 46.013  1.9725      72
 50.230  1.8163     450
 50.287  1.8144     244
 54.971  1.6703     160
 60.049  1.5407     256

    65.500    1.4250
A5256+A5257A  11-04-1984  13.38  PROGRAM 214
```



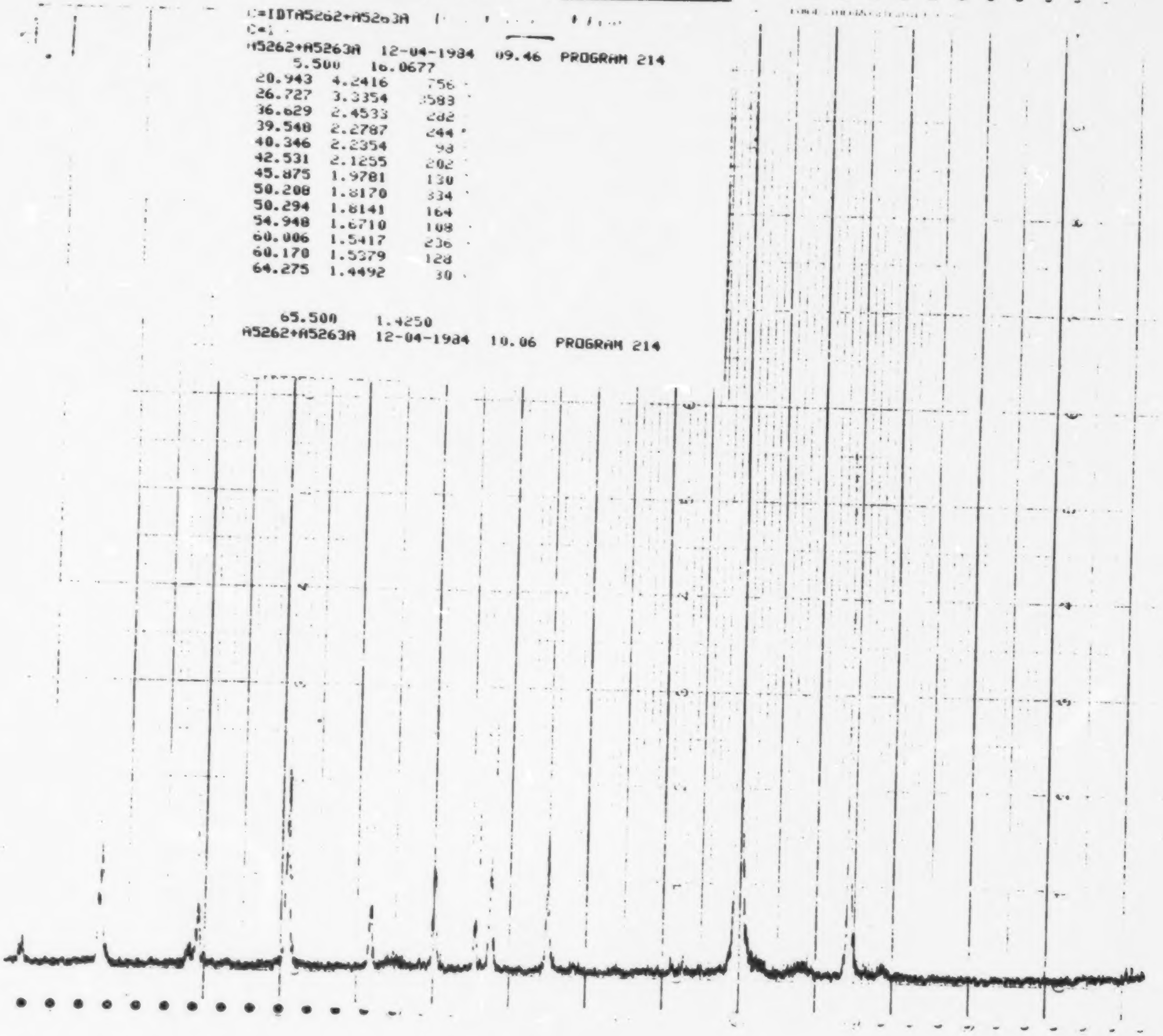
```
A5258-A5259A  16-04-1984  15.44  PROGRAM 214
     5.500   16.0677
  20.823   4.2657      644
  25.469   3.4973       52
  26.605   3.3491     3210
  36.520   2.4603      234
  39.441   2.2846      102
  40.267   2.2336      100
  42.435   2.1301      124
  45.769   1.9824      112
  50.103   1.8206      352
  50.210   1.8167      140
  54.824   1.6745      140
  59.902   1.5441      208
  60.040   1.5409      124

    65.500     1.4250
A5258+A5259A  16-04-1984  16.05  PROGRAM 214
```



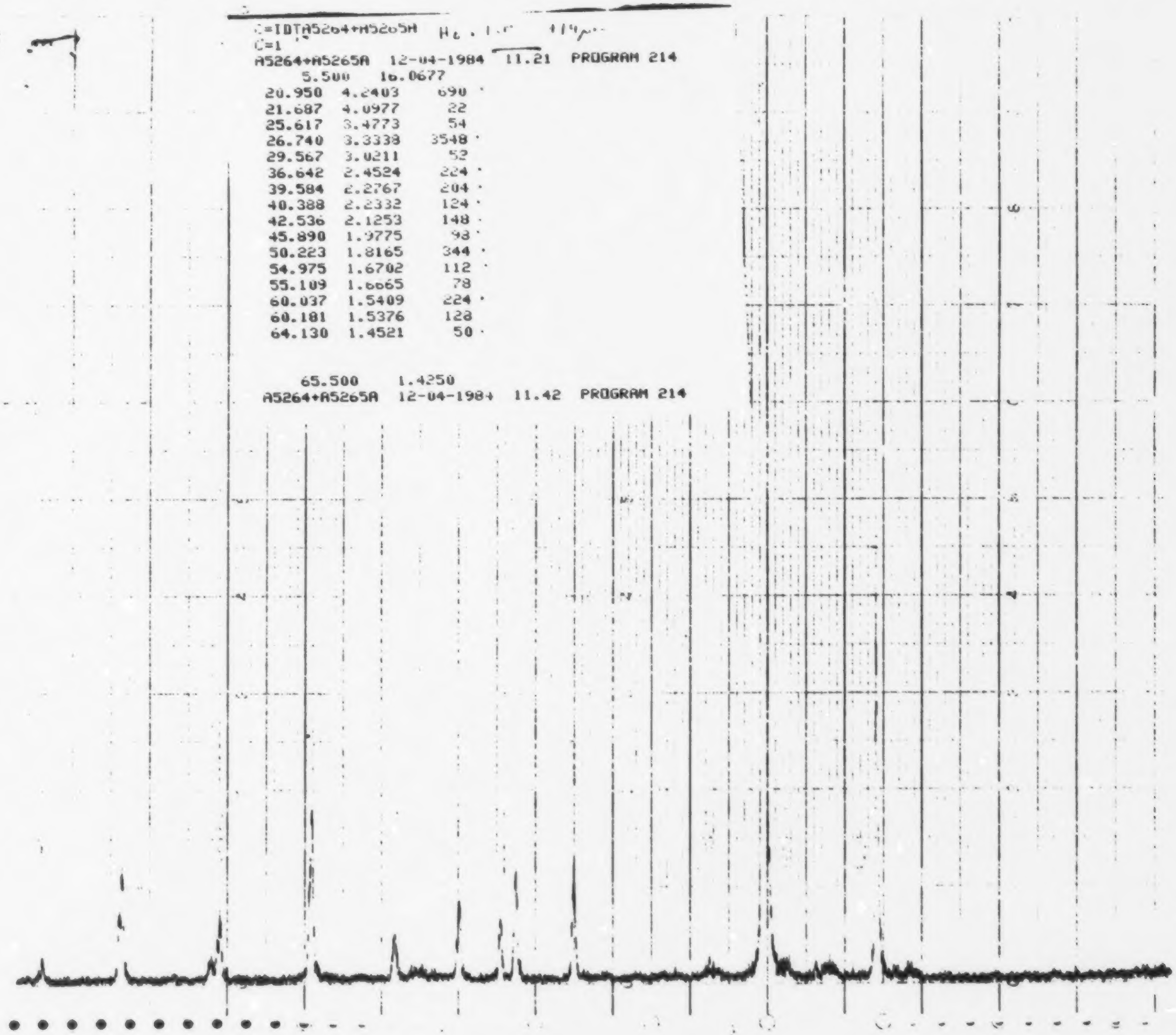
```
C=IDTA5260+A5261A
C=1
A5260+A5261A  12-04-1984  08.12  PROGRAM 214
     5.500   16.0677
 20.971  4.2360     759
 24.127  3.6836      52
 25.788  3.4546      59
 26.755  3.3319    3716
 36.665  2.4510     280
 39.572  2.2774     198
 40.442  2.2303     116
 42.537  2.1252     196
 45.919  1.9763     144
 50.240  1.8160     408
 50.377  1.8113     242
 54.983  1.6700     120
 55.424  1.6578      40
 60.081  1.5399     212
 60.210  1.5369     164
 64.101  1.4527      55

     65.500    1.4250
 A5260+A5261A  12-04-1984  08.33  PROGRAM 214
```



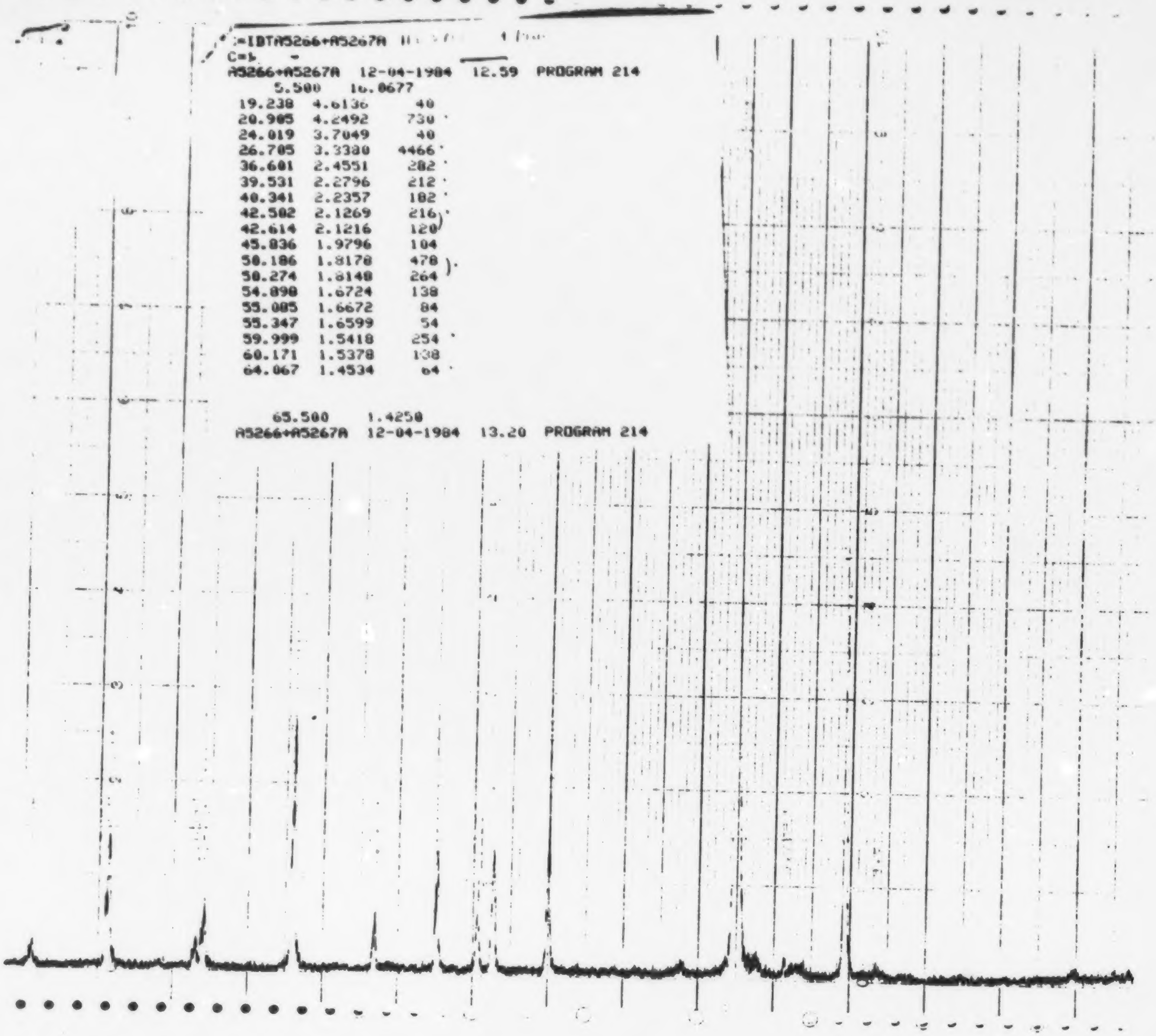
```
C=IDTA5262+A5263A
C=1
A5262+A5263A  12-04-1984  09.46  PROGRAM 214
     5.500   16.0677
  20.943  4.2416     756
  26.727  3.3354    3583
  36.629  2.4533     282
  39.548  2.2787     244
  40.346  2.2354      98
  42.531  2.1255     202
  45.875  1.9781     130
  50.208  1.8170     334
  50.294  1.8141     164
  54.948  1.6710     108
  60.006  1.5417     236
  60.170  1.5379     128
  64.275  1.4492      30

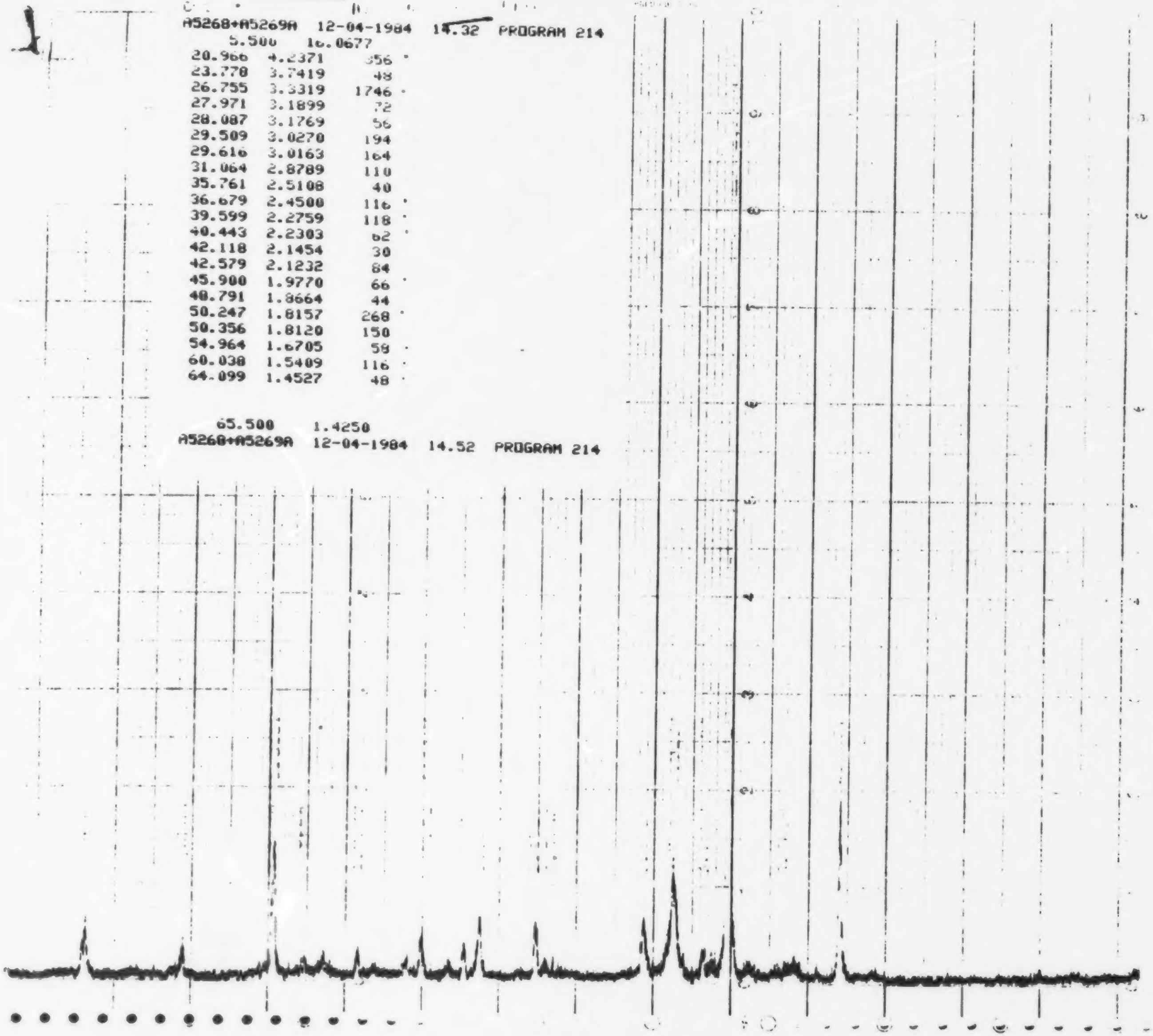

    65.500    1.4250
A5262+A5263A  12-04-1984  10.06  PROGRAM 214
```



```
C=IDTA5264+A5265A  Hc . 1.r   414μ
C=1
A5264+A5265A  12-04-1984  11.21  PROGRAM 214
     5.500   16.0677
 20.950  4.2403     690 ·
 21.687  4.0977      22
 25.617  3.4773      54
 26.740  3.3338    3548 ·
 29.567  3.0211      52
 36.642  2.4524     224 ·
 39.584  2.2767     204 ·
 40.388  2.2332     124 ·
 42.536  2.1253     148 ·
 45.890  1.9775      98 ·
 50.223  1.8165     344 ·
 54.975  1.6702     112 ·
 55.109  1.6665      78
 60.037  1.5409     224 ·
 60.181  1.5376     128
 64.130  1.4521      50 ·

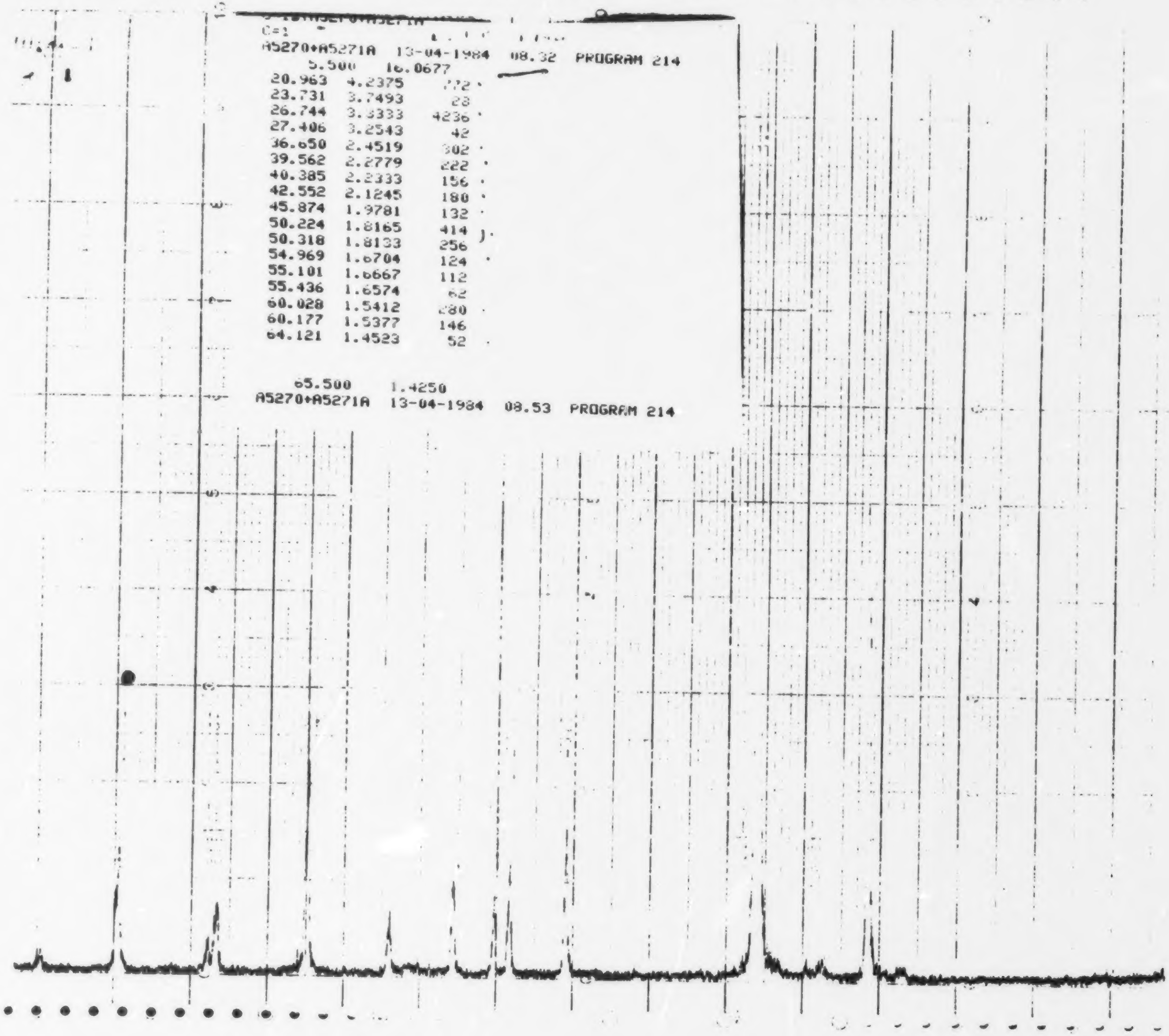

    65.500    1.4250
 A5264+A5265A  12-04-1984  11.42  PROGRAM 214
```





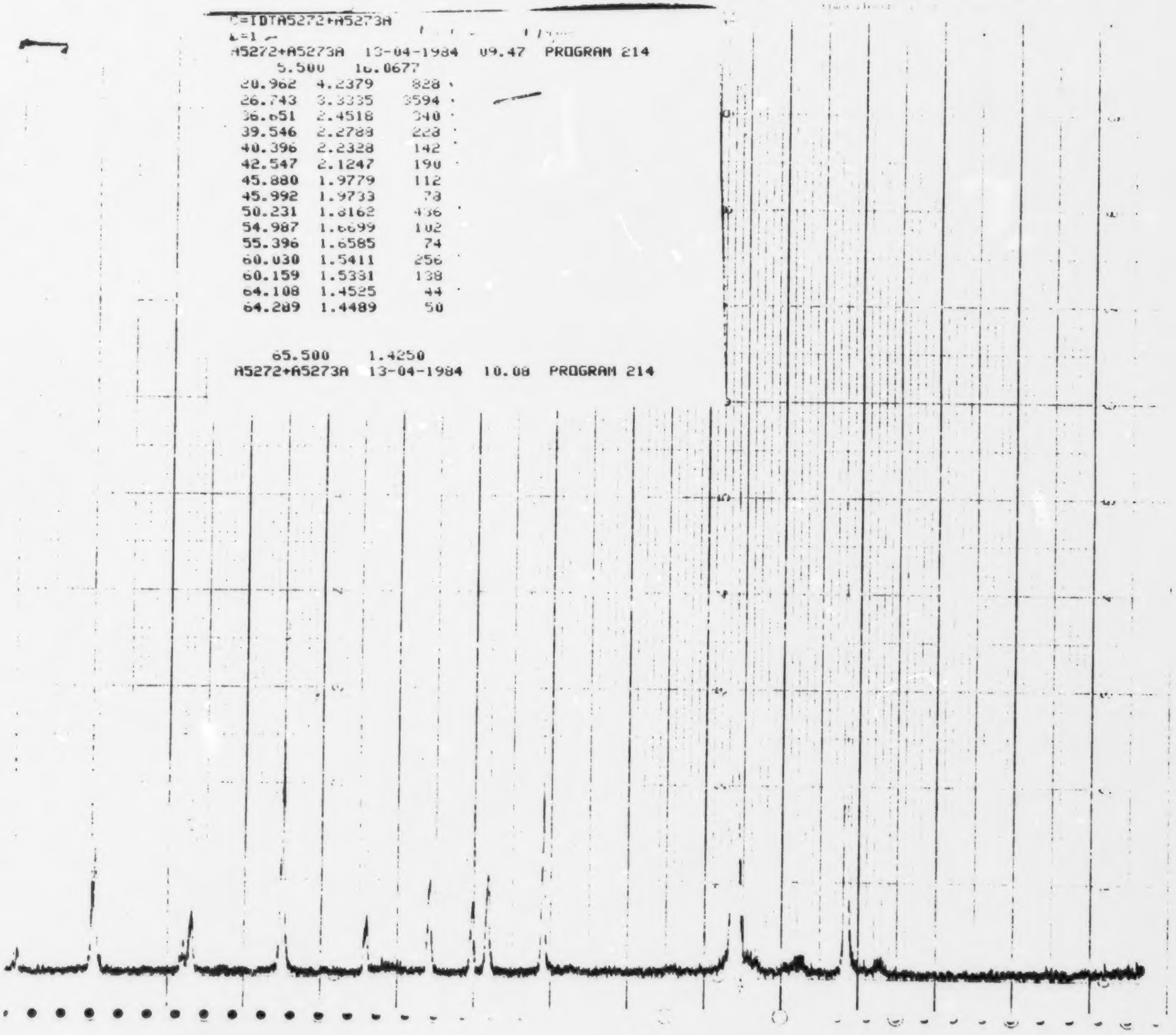
```
A5268+A5269A  12-04-1984  14.32  PROGRAM 214
      5.500   16.0677
  20.966   4.2371     356
  23.778   3.7419      48
  26.755   3.3319    1746
  27.971   3.1899      72
  28.087   3.1769      56
  29.509   3.0270     194
  29.616   3.0163     164
  31.064   2.8789     110
  35.761   2.5108      40
  36.679   2.4500     116
  39.599   2.2759     118
  40.443   2.2303      62
  42.118   2.1454      30
  42.579   2.1232      84
  45.900   1.9770      66
  48.791   1.8664      44
  50.247   1.8157     268
  50.356   1.8120     150
  54.964   1.6705      58
  60.038   1.5409     116
  64.099   1.4527      48


     65.500    1.4250
A5268+A5269A  12-04-1984  14.52  PROGRAM 214
```



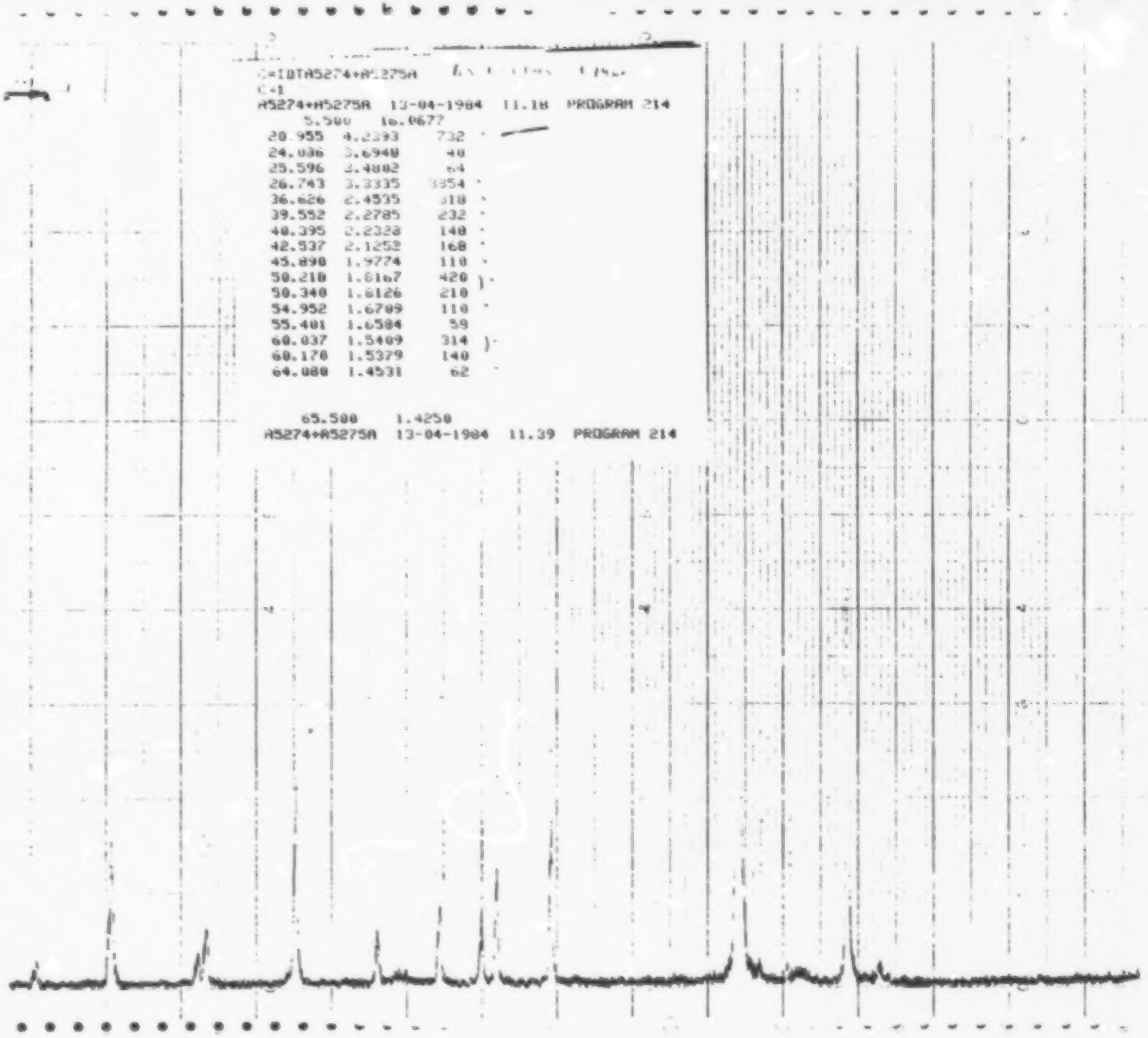
```
C=1
A5270+A5271A  13-04-1984  08.32  PROGRAM 214
     5.500   16.0677
 20.963  4.2375    772 .
 23.731  3.7493     28
 26.744  3.3333   4236 .
 27.406  3.2543     42
 36.650  2.4519    302 .
 39.562  2.2779    222  .
 40.385  2.2333    156  .
 42.552  2.1245    180  .
 45.874  1.9781    132  .
 50.224  1.8165    414 ).
 50.318  1.8133    256
 54.969  1.6704    124  .
 55.101  1.6667    112
 55.436  1.6574     62
 60.028  1.5412    280  .
 60.177  1.5377    146
 64.121  1.4523     52  .

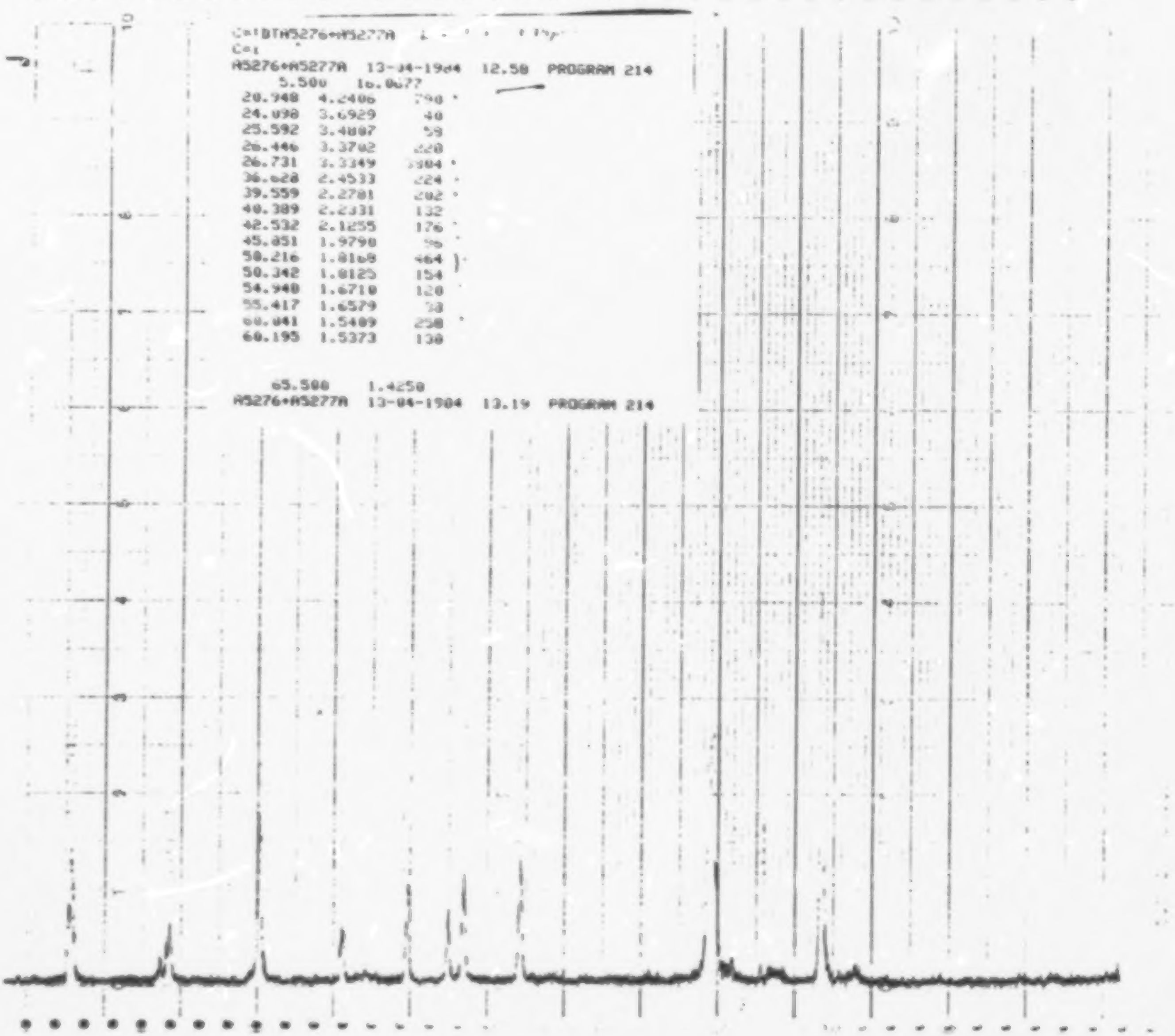

    65.500    1.4250
A5270+A5271A  13-04-1984  08.53  PROGRAM 214
```



```
C=IDTA5272+A5273A
L=1
A5272+A5273A  13-04-1984  09.47  PROGRAM 214
     5.500   16.0677
 20.962  4.2379    828
 26.743  3.3335   3594
 36.651  2.4518    340
 39.546  2.2788    228
 40.396  2.2328    142
 42.547  2.1247    190
 45.880  1.9779    112
 45.992  1.9733     78
 50.231  1.8162    436
 54.987  1.6699    102
 55.396  1.6585     74
 60.030  1.5411    256
 60.159  1.5331    138
 64.108  1.4525     44
 64.289  1.4489     50

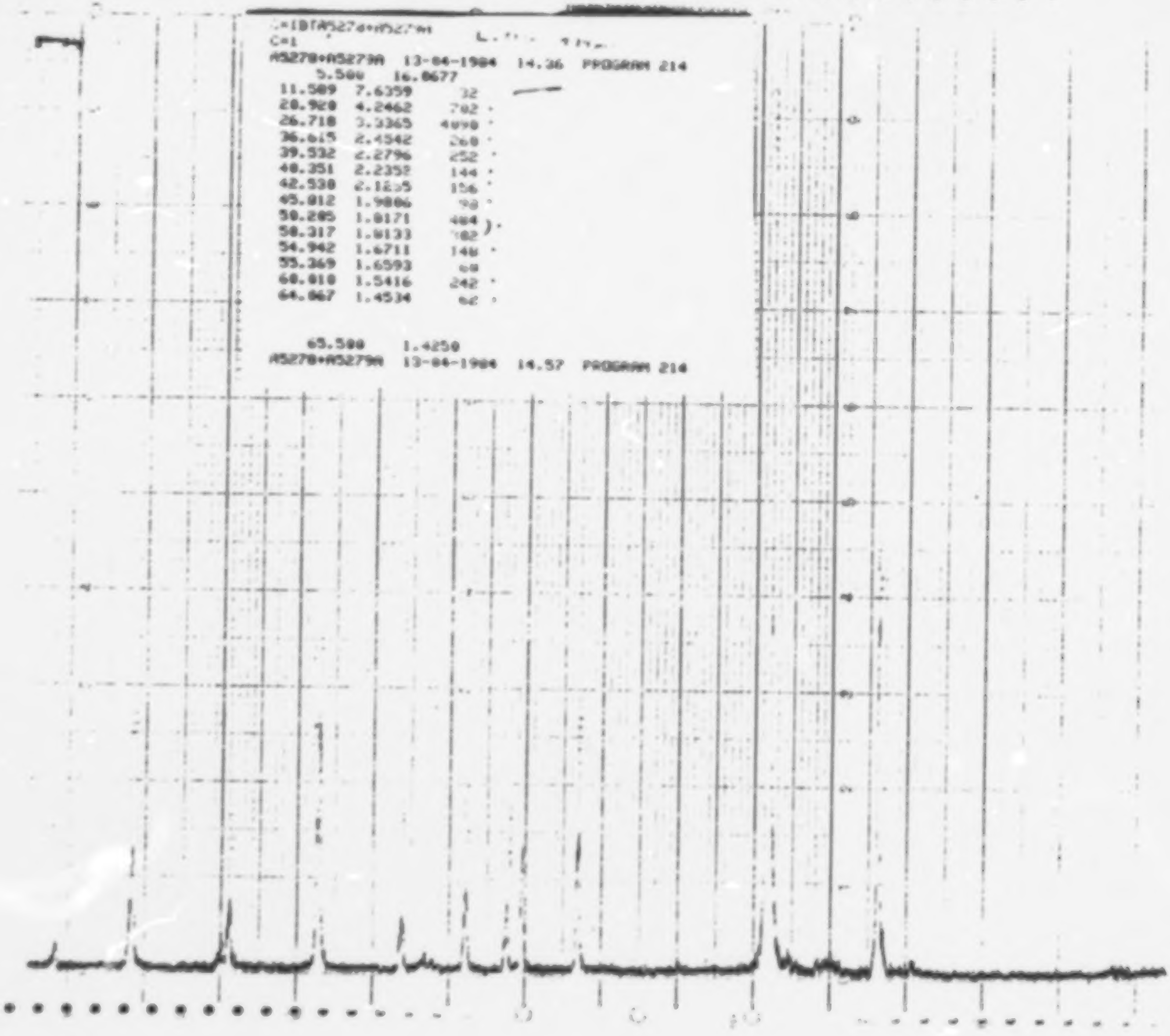

     65.500    1.4250
A5272+A5273A  13-04-1984  10.08  PROGRAM 214
```





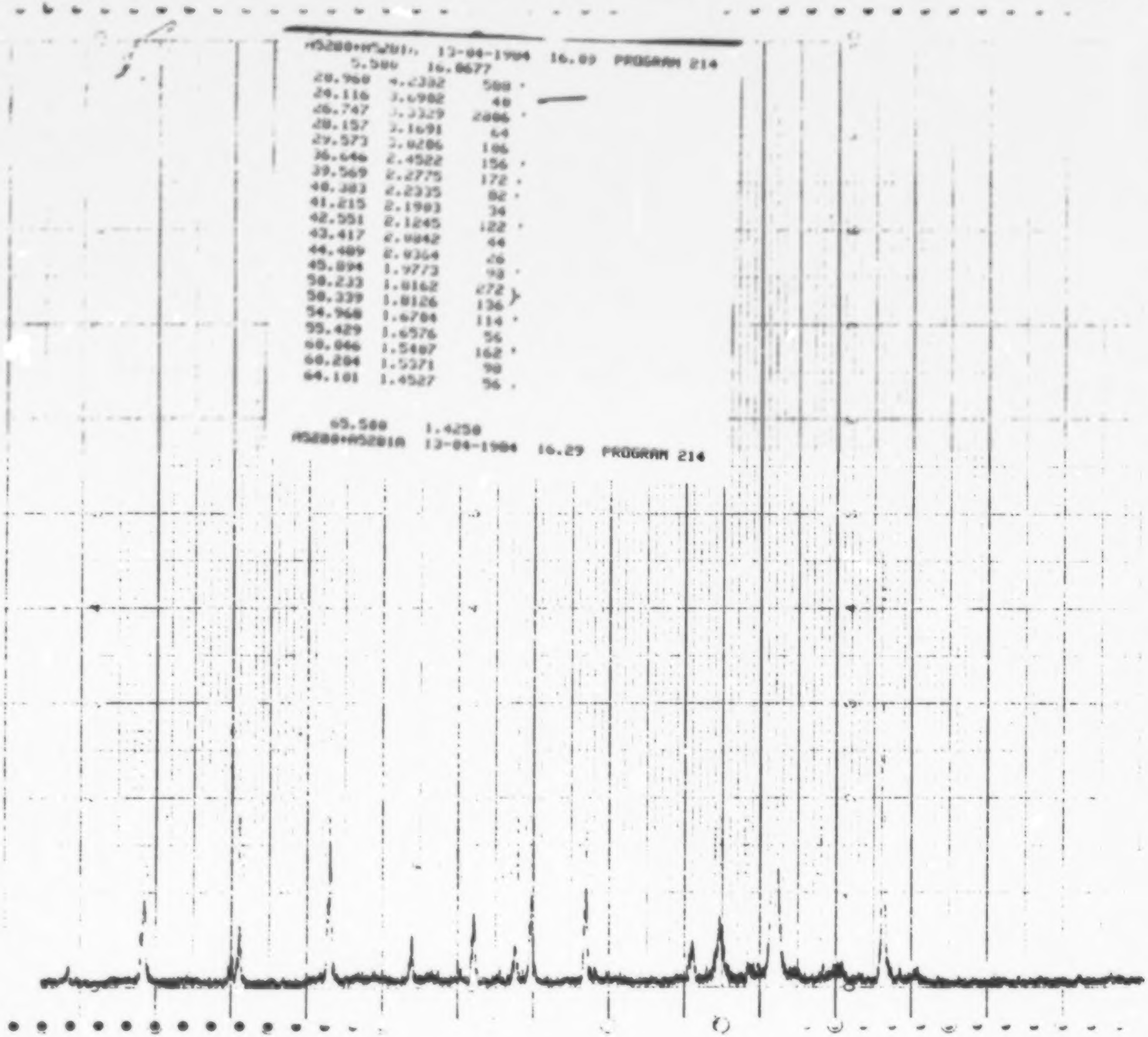
```
C=!DTA5276+A5277A
C=1
A5276+A5277A  13-04-1984  12.50  PROGRAM 214
     5.500   16.0677
  20.948  4.2406      790 .
  24.098  3.6929       40
  25.592  3.4887       59
  26.446  3.3702      220
  26.731  3.3349     3304 .
  36.628  2.4533      224 .
  39.559  2.2781      202 .
  40.389  2.2331      132
  42.532  2.1255      176 .
  45.851  1.9790       96 .
  50.216  1.8168      464 ).
  50.342  1.8125      154
  54.940  1.6710      120 .
  55.417  1.6579       38
  60.041  1.5409      258 .
  60.195  1.5373      130


     65.500    1.4250
A5276+A5277A  13-04-1984  13.19  PROGRAM 214
```



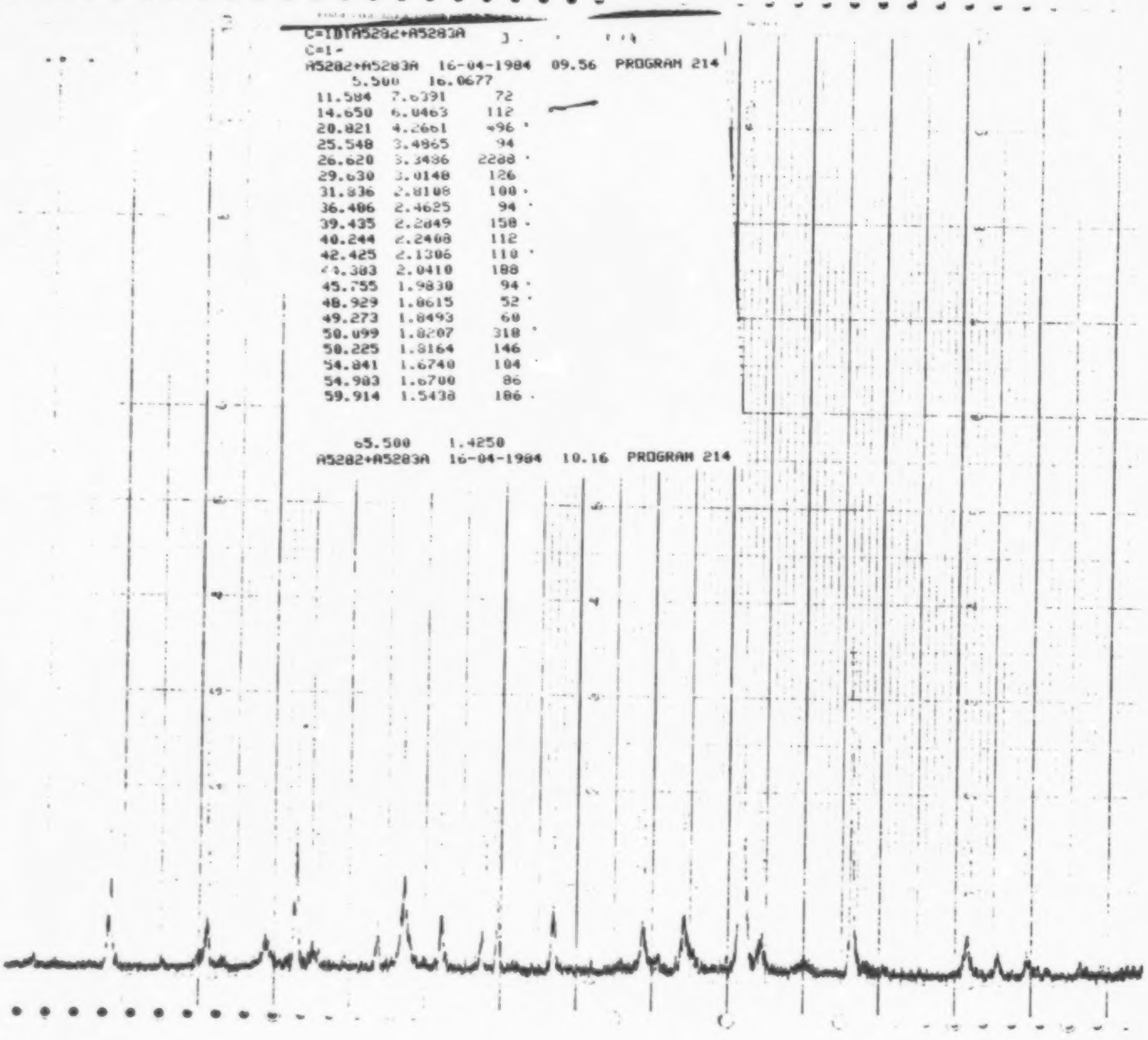
```
C=IDTA527a+A527?A
C=1
A5270+A5279A  13-04-1984  14.36  PROGRAM 214
     5.500   16.0677
  11.589   7.6359      32
  20.920   4.2462     702
  26.718   3.3365    4090
  36.615   2.4542     260
  39.532   2.2796     252
  40.351   2.2352     144
  42.530   2.1235     156
  45.812   1.9806      98
  50.205   1.8171     404 )
  50.317   1.8133     782
  54.942   1.6711     148
  55.369   1.6593      68
  60.010   1.5416     242
  64.067   1.4534      62


     65.500     1.4250
A5270+A5279A  13-04-1984  14.57  PROGRAM 214
```



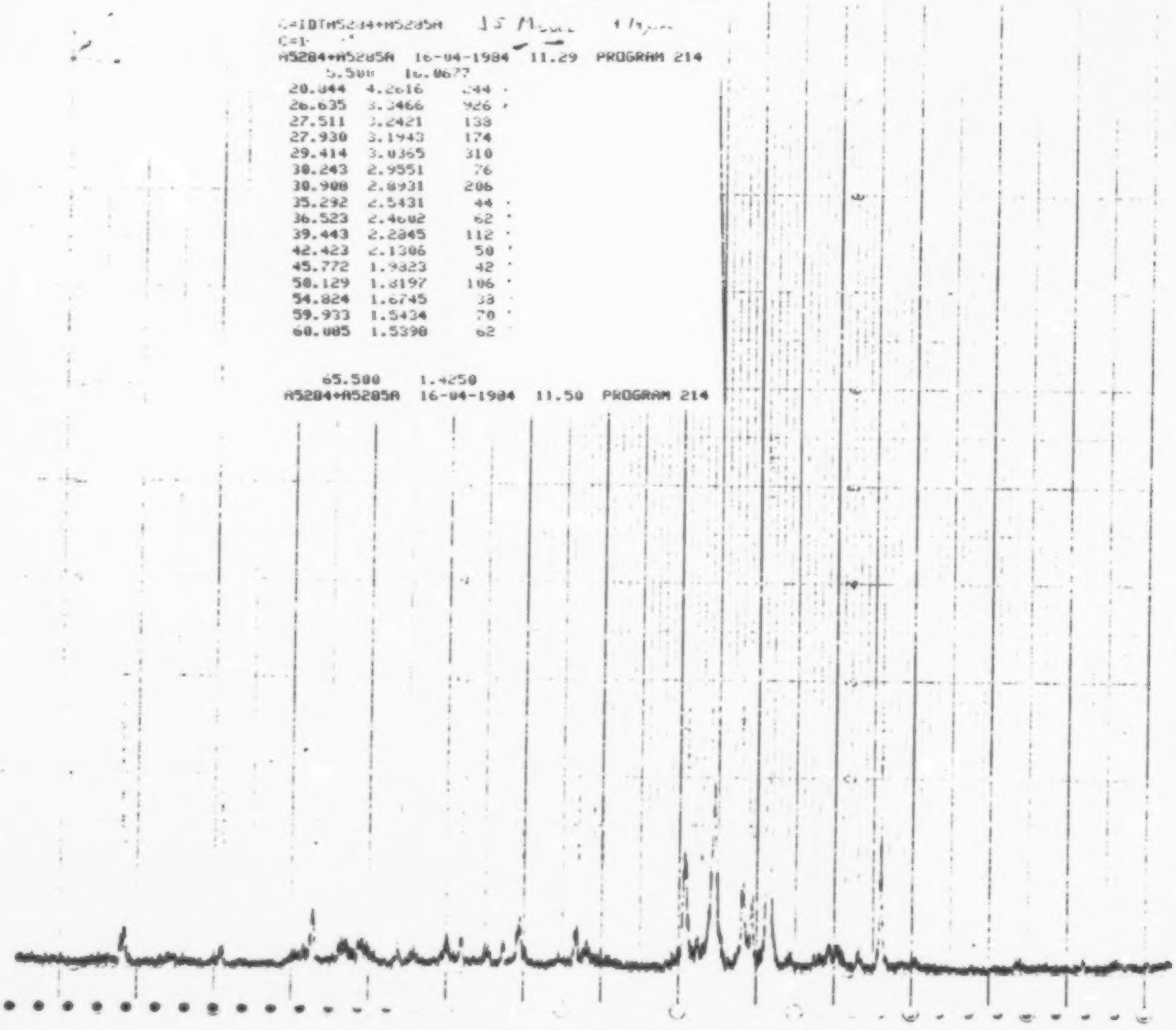
```
HS280+HS281A  13-04-1984  16.09  PROGRAM 214
      5.500   16.0677
   20.960   4.2332     500 .
   24.116   3.6902      40
   26.747   3.3329    2006 .
   28.157   3.1691      64
   29.573   3.0206     106
   36.646   2.4522     156 .
   39.569   2.2775     172 .
   40.383   2.2335      82 .
   41.215   2.1903      34
   42.551   2.1245     122 .
   43.417   2.0842      44
   44.409   2.0364      26
   45.894   1.9773      98 .
   50.233   1.8162     272
   50.339   1.8126     136
   54.968   1.6704     114 .
   55.429   1.6576      56
   60.046   1.5407     162 .
   60.204   1.5371      90
   64.101   1.4527      56 .

     65.500    1.4250
HS280+HS281A  13-04-1984  16.29  PROGRAM 214
```



```
C=IDTA5282+A5283A
C=1-
A5282+A5283A  16-04-1984  09.56  PROGRAM 214
      5.500   16.0677
  11.584  7.6391     72
  14.650  6.0463    112
  20.821  4.2661    496 .
  25.548  3.4865     94
  26.620  3.3486   2288 .
  29.630  3.0148    126
  31.836  2.8108    100 .
  36.486  2.4625     94 .
  39.435  2.2849    158 .
  40.244  2.2408    112
  42.425  2.1306    110 .
  44.383  2.0410    188
  45.755  1.9830     94 .
  48.929  1.8615     52 .
  49.273  1.8493     60
  50.099  1.8207    318 .
  50.225  1.8164    146
  54.841  1.6740    104 .
  54.983  1.6700     86
  59.914  1.5438    186 .

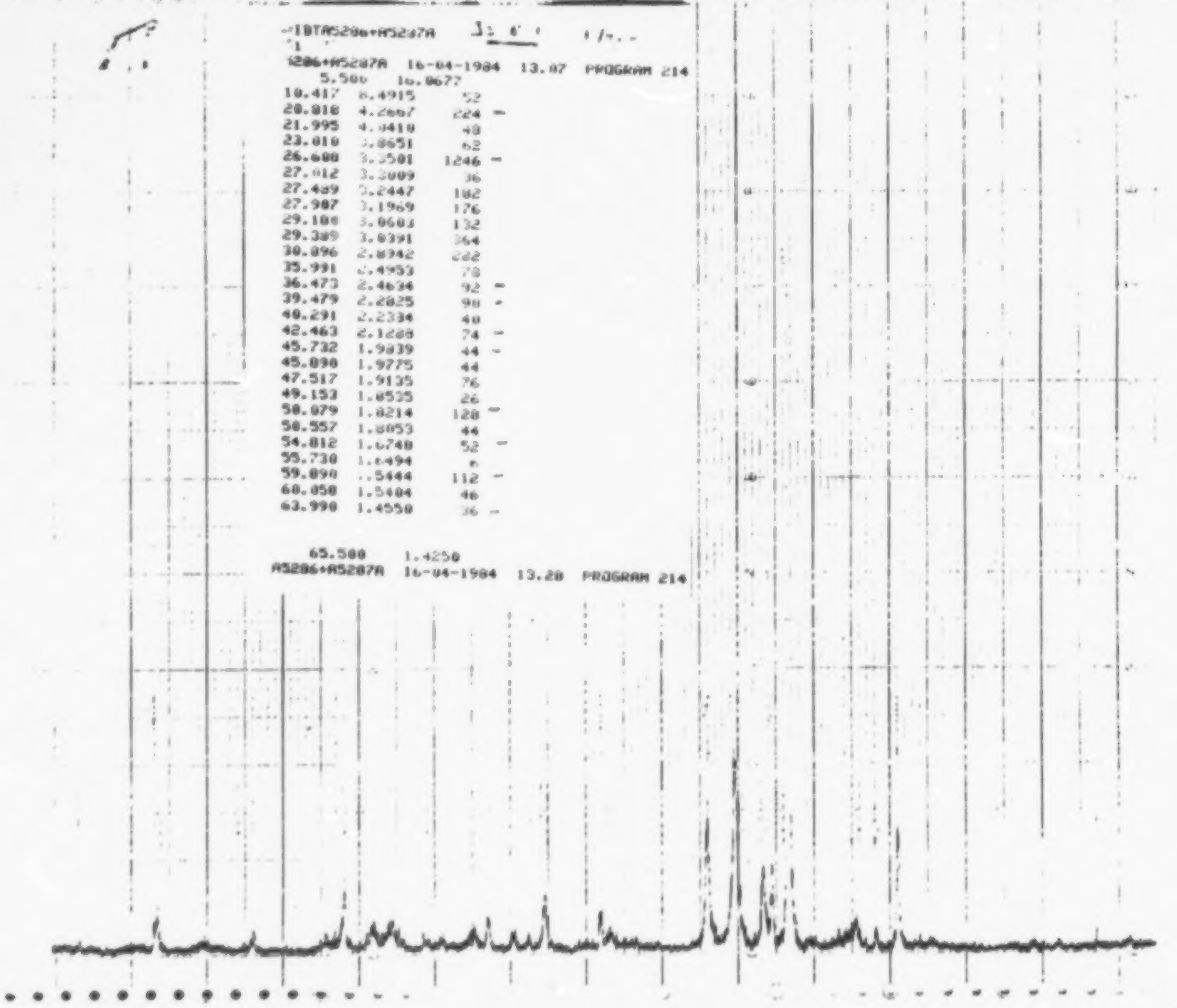
     65.500    1.4250
A5282+A5283A  16-04-1984  10.16  PROGRAM 214
```



```
C=IDTA5284+A5285A
C=1
A5284+A5285A  16-04-1984  11.29  PROGRAM 214
     5.500   16.0677
 20.844  4.2616     244
 26.635  3.3466     926
 27.511  3.2421     138
 27.930  3.1943     174
 29.414  3.0365     310
 30.243  2.9551      76
 30.900  2.8931     206
 35.292  2.5431      44
 36.523  2.4602      62
 39.443  2.2845     112
 42.423  2.1306      50
 45.772  1.9823      42
 50.129  1.8197     106
 54.824  1.6745      33
 59.933  1.5434      70
 60.085  1.5390      62

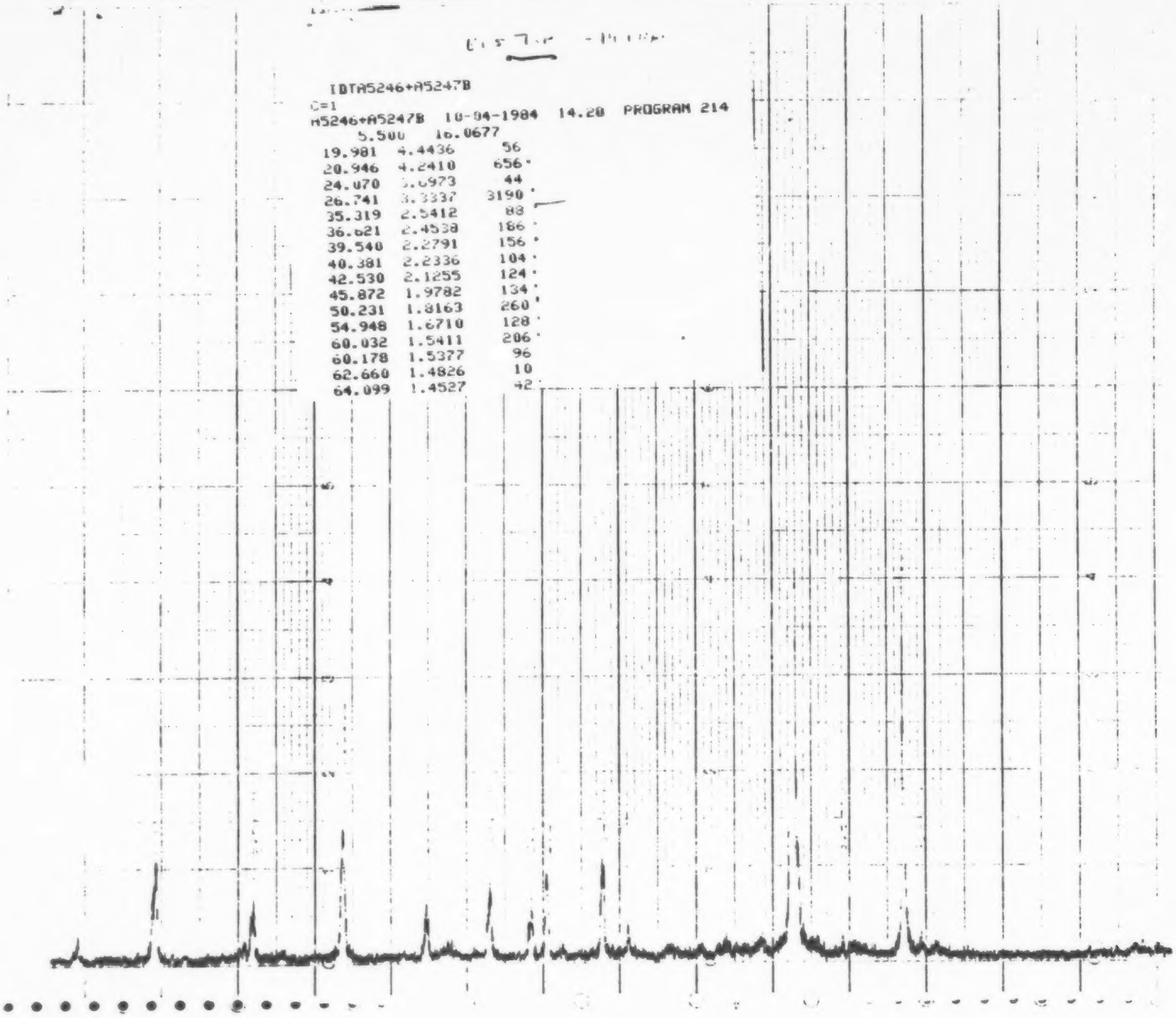

    65.500    1.4250
A5284+A5285A  16-04-1984  11.50  PROGRAM 214
```

15 M[illegible] [illegible]

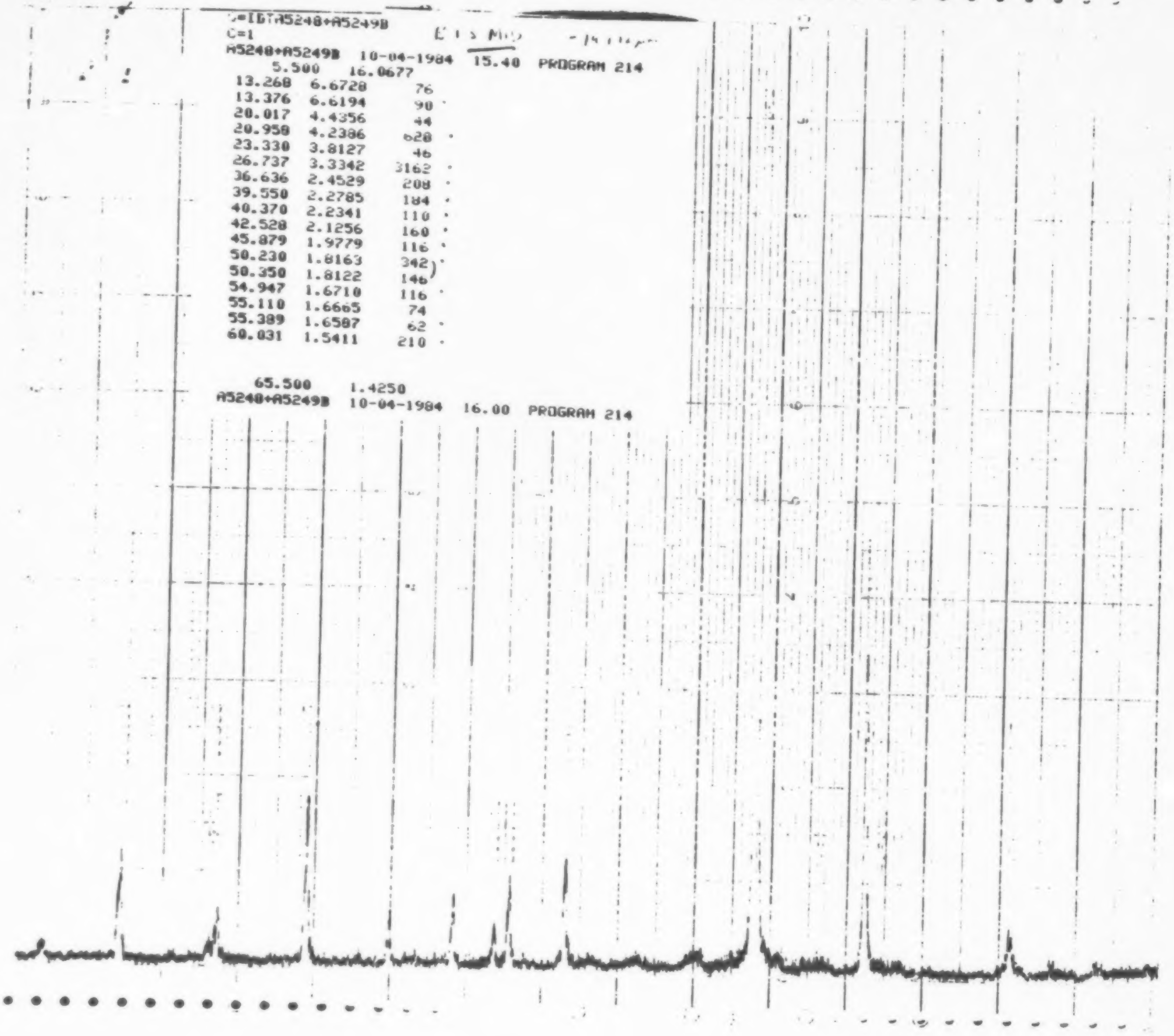


```
-IBTA5206+A5207A   3: 6'   1/-..
 1
5206+A5207A  16-04-1984  13.07  PROGRAM 214
    5.500   16.0677
 10.417  8.4915    52
 20.818  4.2667   224 -
 21.995  4.0410    48
 23.010  3.8651    62
 26.600  3.3501  1246 -
 27.012  3.3009    36
 27.489  3.2447   182
 27.987  3.1969   176
 29.108  3.0603   132
 29.389  3.0391   364
 30.896  2.8942   222
 35.991  2.4953    78
 36.473  2.4634    92 -
 39.479  2.2825    98 -
 40.291  2.2334    48
 42.463  2.1268    74 -
 45.732  1.9839    44 -
 45.890  1.9775    44
 47.517  1.9135    76
 49.153  1.8535    26
 50.079  1.8214   128 -
 50.557  1.8053    44
 54.812  1.6740    52 -
 55.730  1.6494     6
 59.890  1.5444   112 -
 60.050  1.5404    46
 63.990  1.4550    36 -

    65.500   1.4250
A5206+A5207A  16-04-1984  13.20  PROGRAM 214
```



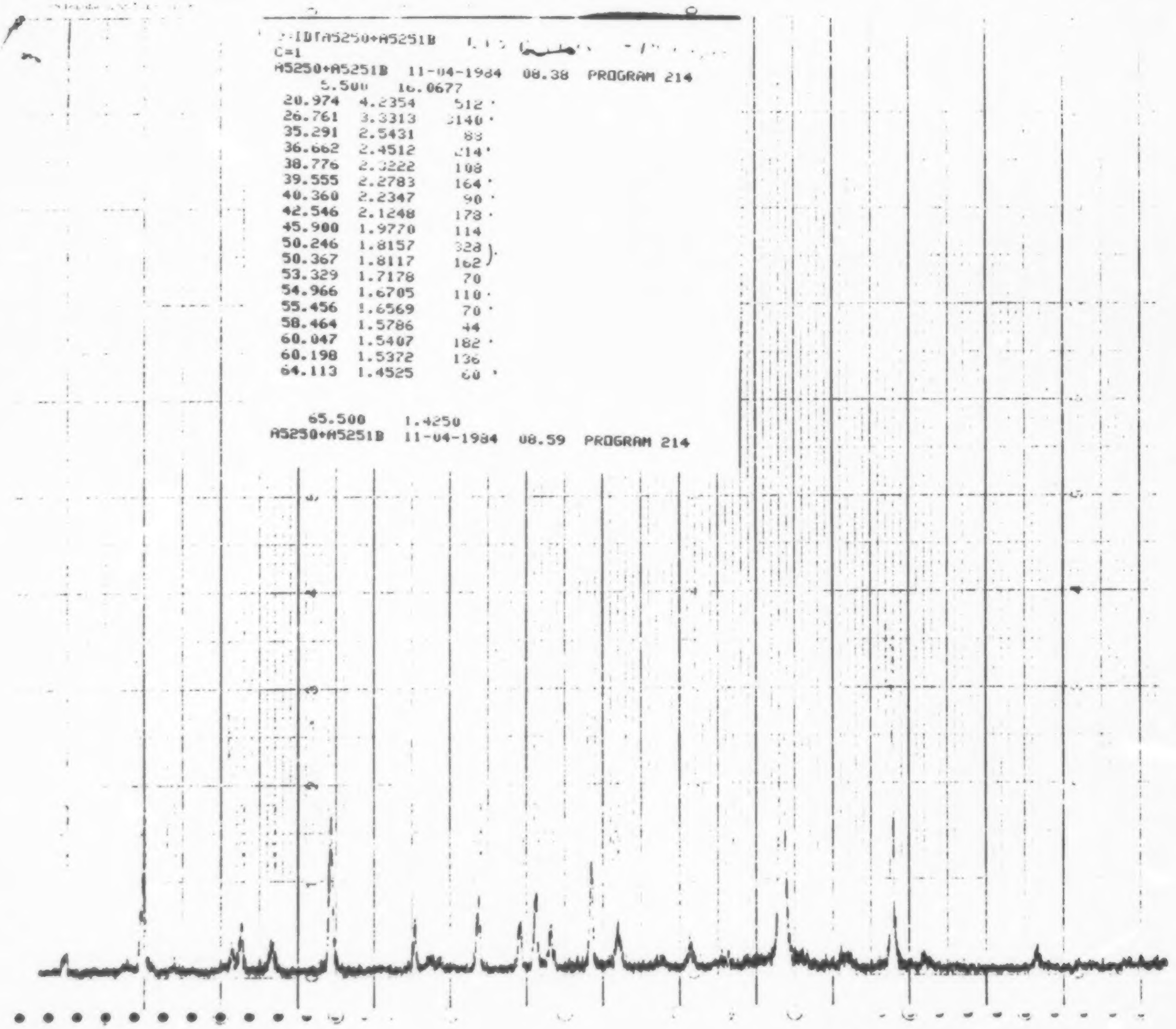
```
IDTA5246+A5247B
C=1
A5246+A5247B  10-04-1984  14.20  PROGRAM 214
     5.500   16.0677
 19.981  4.4436     56
 20.946  4.2410    656
 24.070  3.6973     44
 26.741  3.3337   3190
 35.319  2.5412     88
 36.621  2.4538    186
 39.540  2.2791    156
 40.381  2.2336    104
 42.530  2.1255    124
 45.872  1.9782    134
 50.231  1.8163    260
 54.948  1.6710    128
 60.032  1.5411    206
 60.178  1.5377     96
 62.660  1.4826     10
 64.099  1.4527     42
```



```
=IDTA5248+A5249B
C=1
A5248+A5249B  10-04-1984  15.40  PROGRAM 214
      5.500   16.0677
  13.268   6.6728        76
  13.376   6.6194        90
  20.017   4.4356        44
  20.958   4.2386       628
  23.330   3.8127        46
  26.737   3.3342      3162
  36.636   2.4529       208
  39.550   2.2785       184
  40.370   2.2341       110
  42.528   2.1256       160
  45.879   1.9779       116
  50.230   1.8163       342)
  50.350   1.8122       146
  54.947   1.6710       116
  55.110   1.6665        74
  55.389   1.6587        62
  60.031   1.5411       210

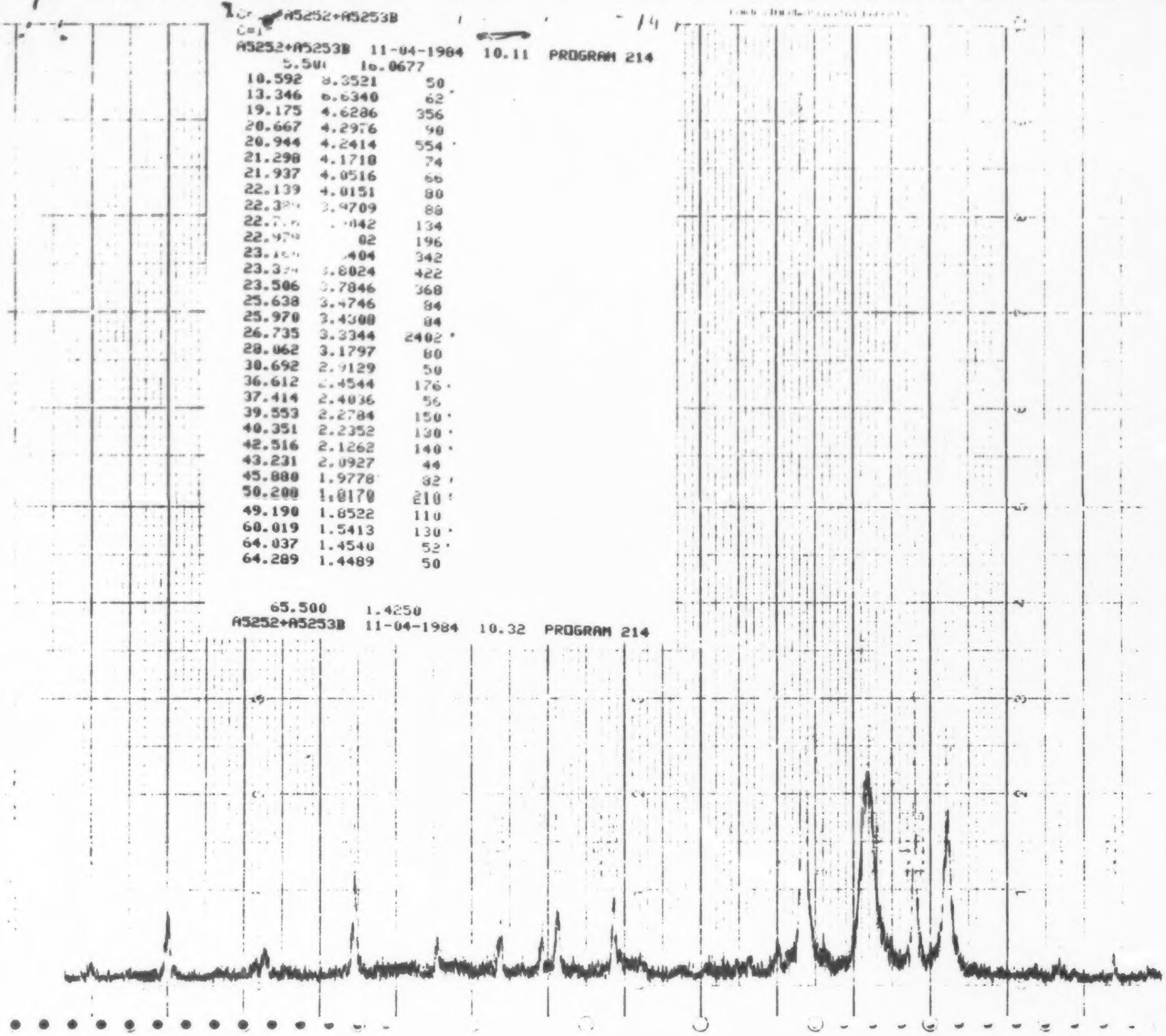
    65.500      1.4250
A5248+A5249B  10-04-1984  16.00  PROGRAM 214
```

E 1 s M[illegible] -14 [illegible]



```
IDTA5250+A5251B
C=1
A5250+A5251B  11-04-1984  08.38  PROGRAM 214
     5.500   16.0677
 20.974  4.2354    512 ·
 26.761  3.3313   3140 ·
 35.291  2.5431     83
 36.662  2.4512    214 ·
 38.776  2.3222    108
 39.555  2.2783    164 ·
 40.360  2.2347     90 ·
 42.546  2.1248    178 ·
 45.900  1.9770    114
 50.246  1.8157    328 ).
 50.367  1.8117    162 )
 53.329  1.7178     70
 54.966  1.6705    110 ·
 55.456  1.6569     70 ·
 58.464  1.5786     44
 60.047  1.5407    182 ·
 60.198  1.5372    136
 64.113  1.4525     60 ·

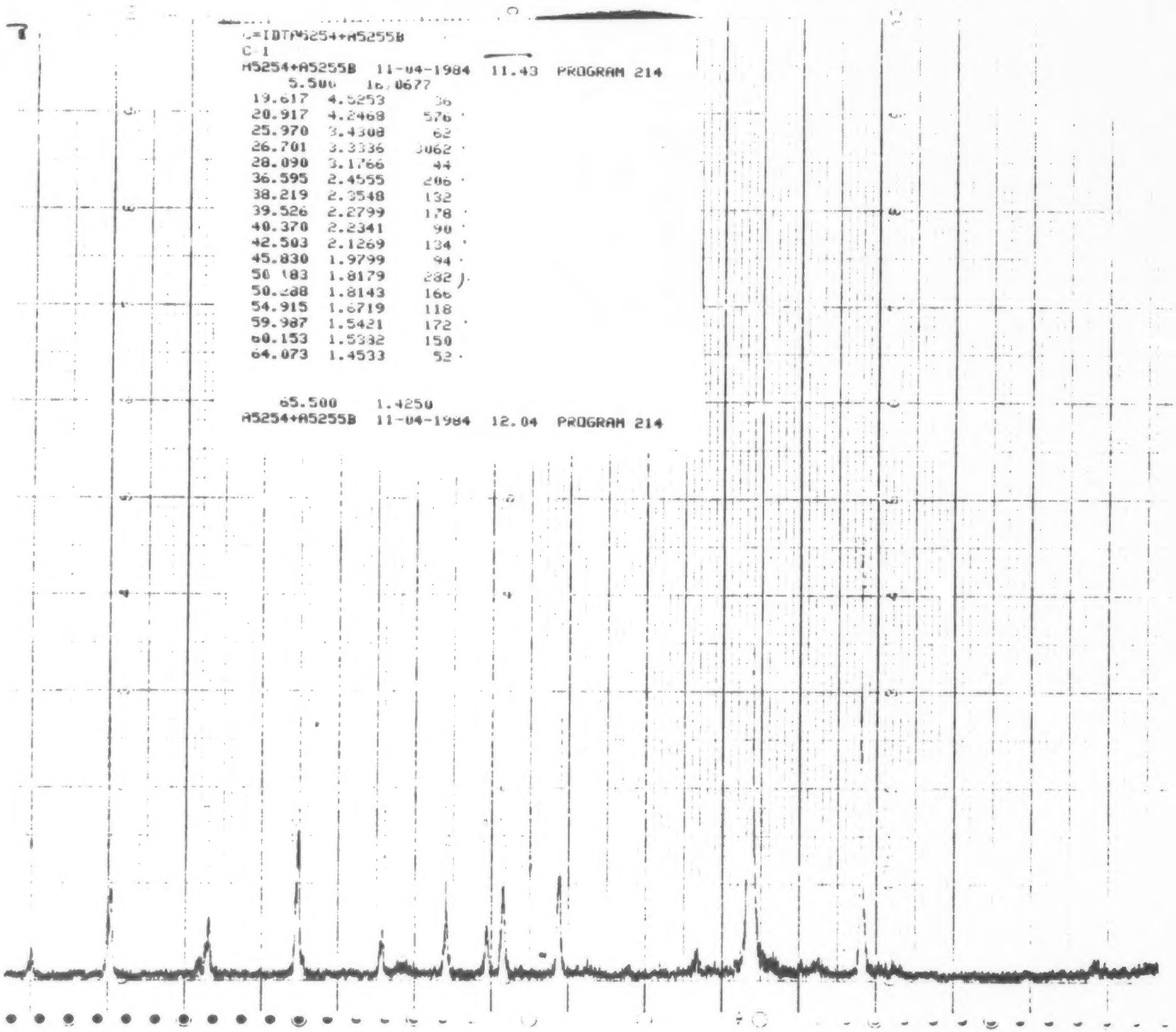

    65.500    1.4250
A5250+A5251B  11-04-1984  08.59  PROGRAM 214
```



14

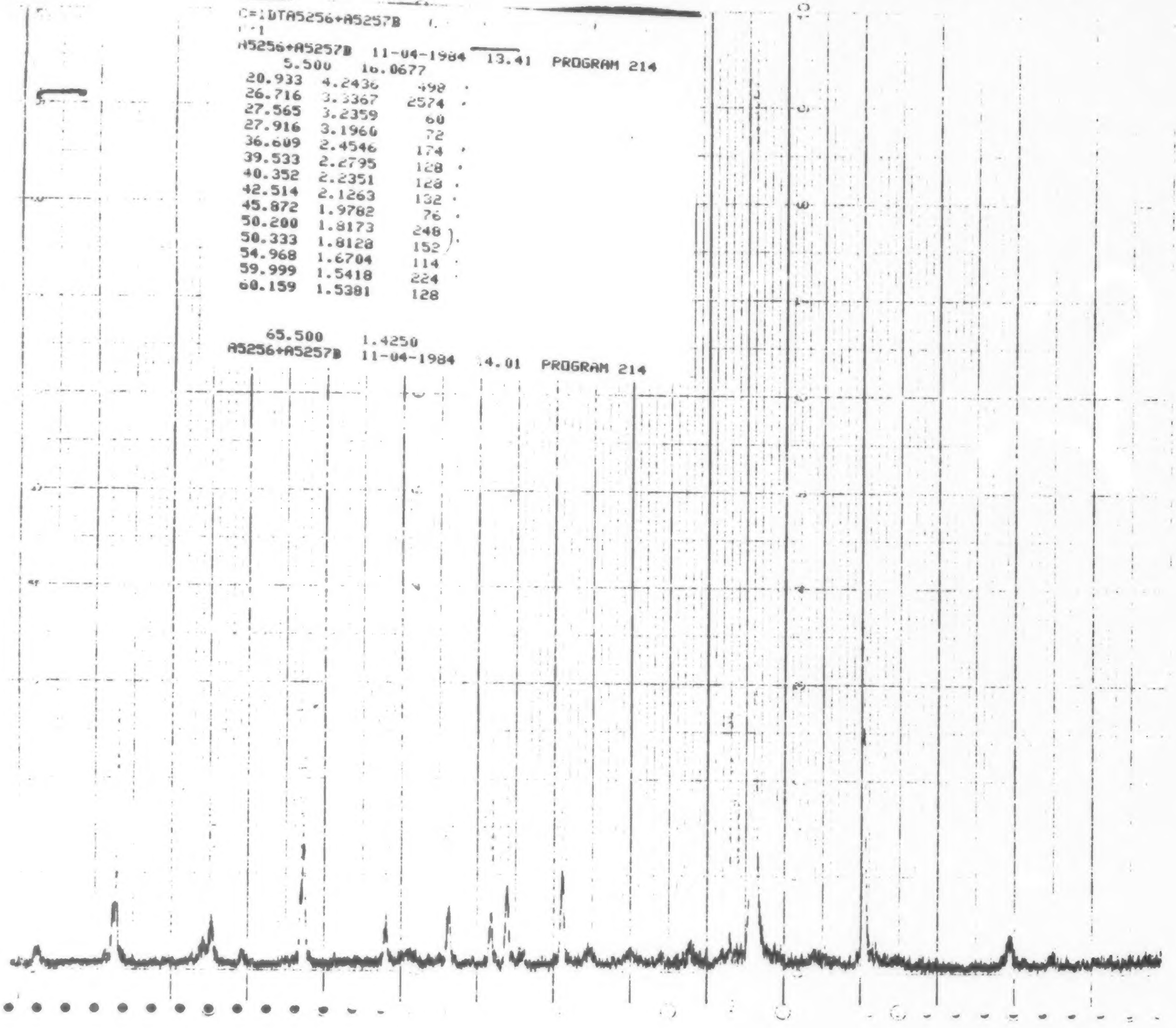
```
A5252+A5253B
C=1
A5252+A5253B  11-04-1984  10.11  PROGRAM 214
      5.500    16.0677
  10.592  8.3521      50
  13.346  6.6340      62
  19.175  4.6286     356
  20.667  4.2976      90
  20.944  4.2414     554
  21.298  4.1710      74
  21.937  4.0516      66
  22.139  4.0151      80
  22.3[illegible]  3.9709      88
  22.[illegible]  [illegible]042     134
  22.9[illegible]  [illegible]02     196
  23.[illegible]  [illegible]404     342
  23.3[illegible]  [illegible].8024     422
  23.506  3.7846     368
  25.638  3.4746      84
  25.970  3.4300      84
  26.735  3.3344    2402
  28.062  3.1797      80
  30.692  2.9129      50
  36.612  2.4544     176
  37.414  2.4036      56
  39.553  2.2784     150
  40.351  2.2352     130
  42.516  2.1262     140
  43.231  2.0927      44
  45.880  1.9778      82
  50.200  1.8170     210
  49.190  1.8522     110
  60.019  1.5413     130
  64.037  1.4540      52
  64.289  1.4489      50

      65.500     1.4250
A5252+A5253B  11-04-1984  10.32  PROGRAM 214
```



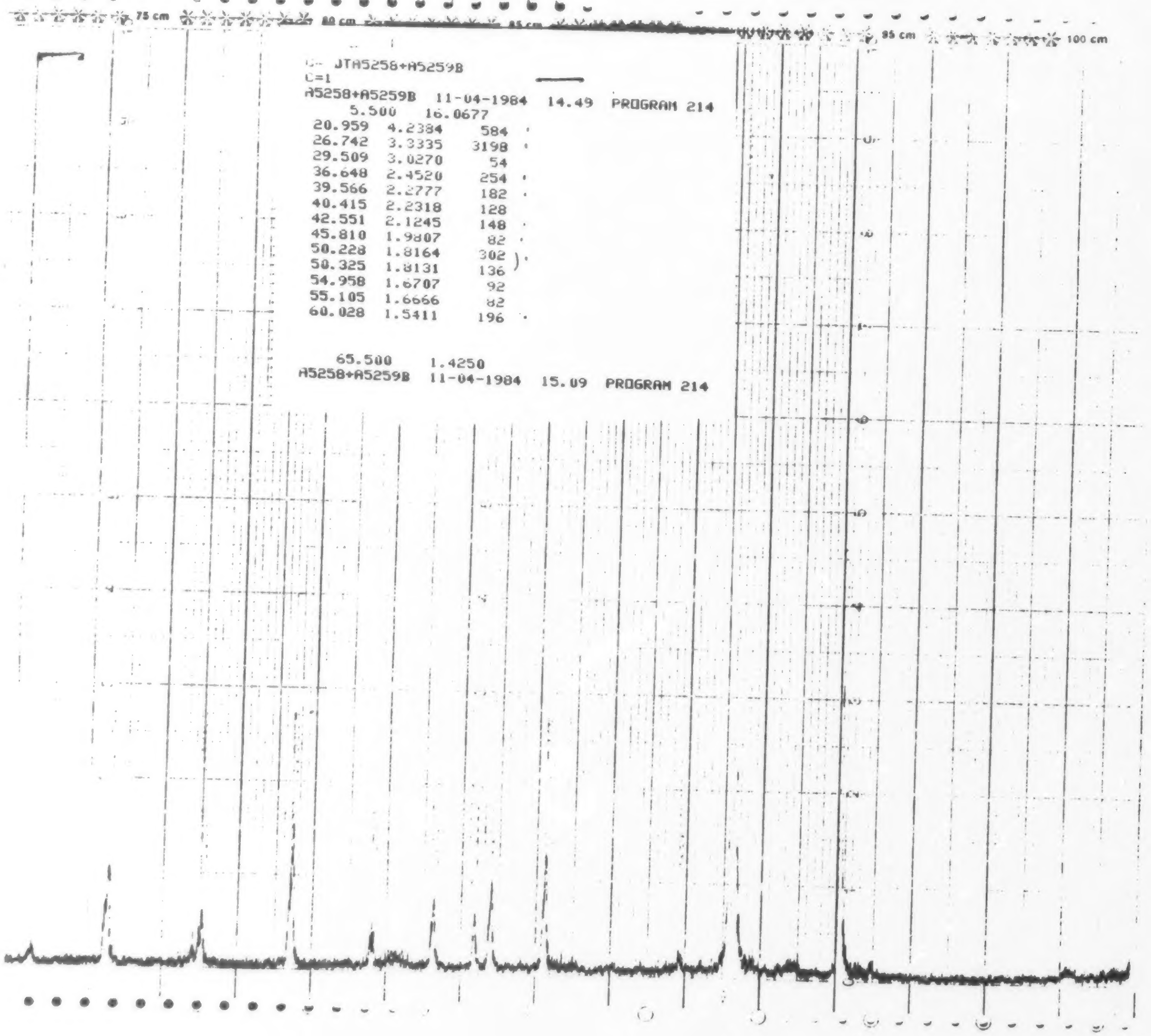
```
=IDTA5254+A5255B
C-1
A5254+A5255B  11-04-1984  11.43  PROGRAM 214
      5.500    16.0677
 19.617  4.5253      36
 20.917  4.2468     576
 25.970  3.4308      62
 26.701  3.3336    3062
 28.090  3.1766      44
 36.595  2.4555     206
 38.219  2.3548     132
 39.526  2.2799     178
 40.370  2.2341      90
 42.503  2.1269     134
 45.830  1.9799      94
 50.183  1.8179     282
 50.288  1.8143     166
 54.915  1.6719     118
 59.987  1.5421     172
 60.153  1.5332     150
 64.073  1.4533      52


     65.500    1.4250
A5254+A5255B  11-04-1984  12.04  PROGRAM 214
```



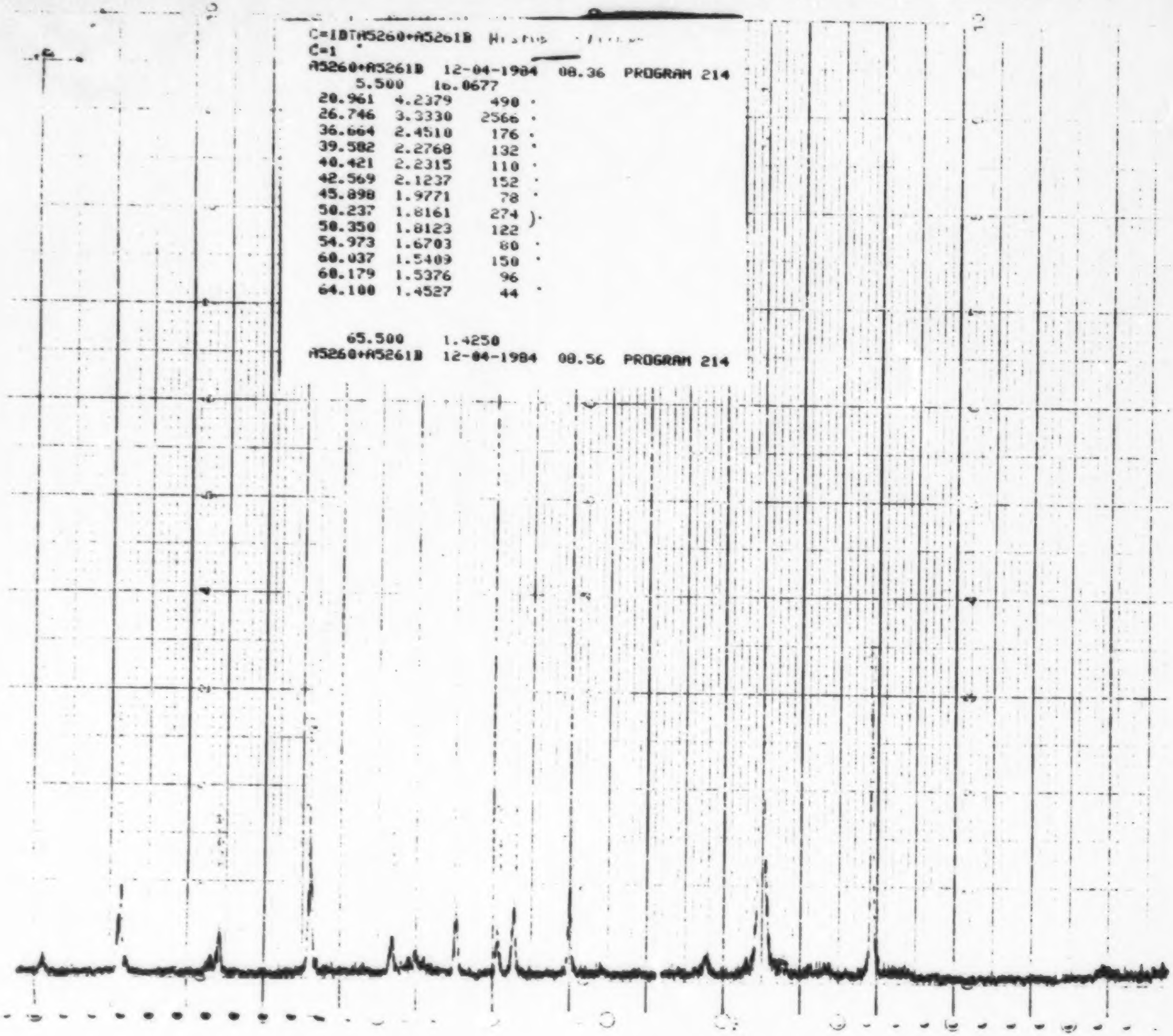
```
C=:DTA5256+A5257B
 ·1
A5256+A5257B  11-04-1984  13.41  PROGRAM 214
     5.500   16.0677
  20.933   4.2436     498
  26.716   3.3367    2574
  27.565   3.2359      60
  27.916   3.1960      72
  36.609   2.4546     174
  39.533   2.2795     128
  40.352   2.2351     128
  42.514   2.1263     132
  45.872   1.9782      76
  50.200   1.8173     248
  50.333   1.8128     152
  54.968   1.6704     114
  59.999   1.5418     224
  60.159   1.5381     128


    65.500    1.4250
A5256+A5257B  11-04-1984  4.01  PROGRAM 214
```



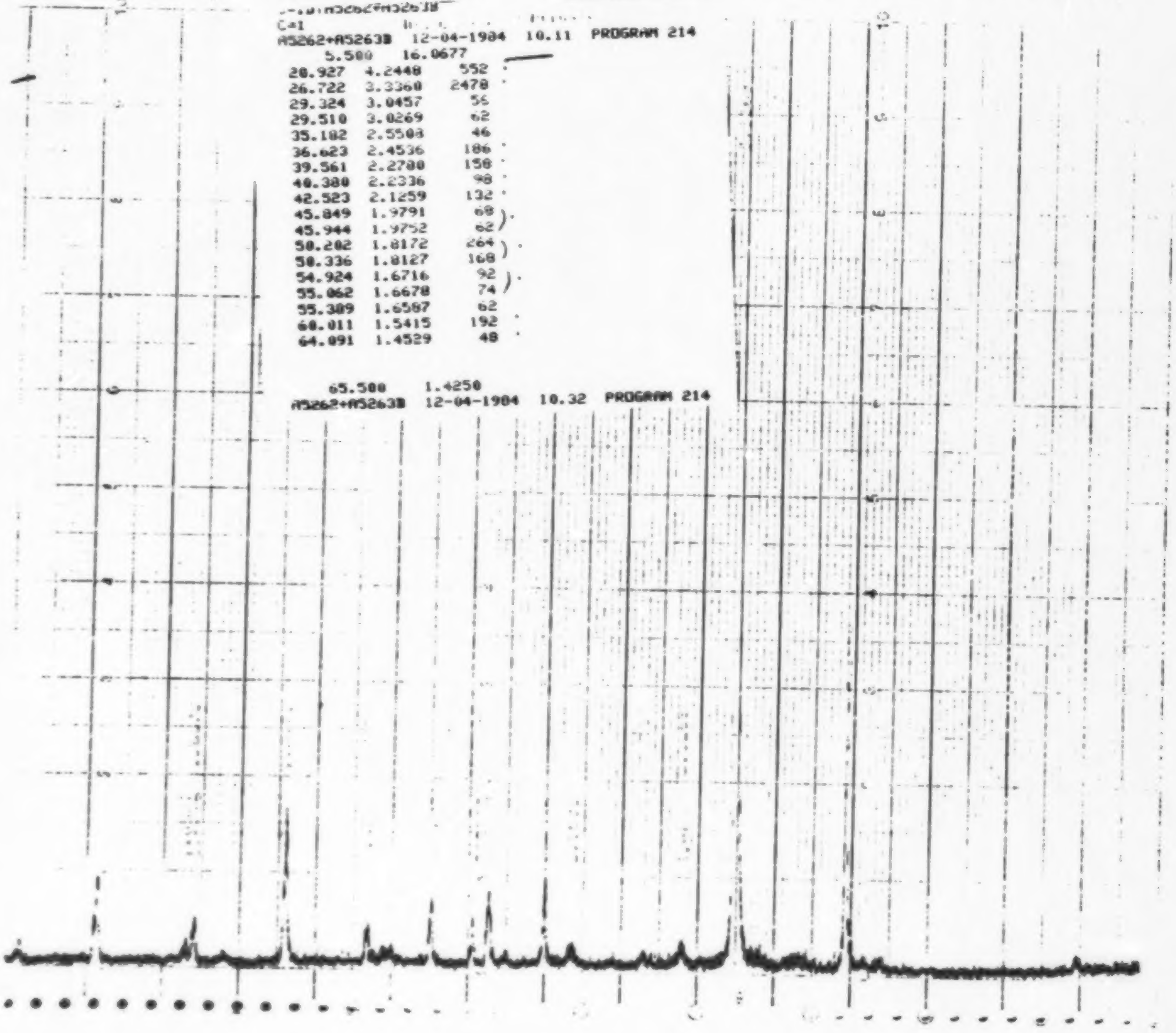
```
  JTA5258+A5259B
C=1
A5258+A5259B  11-04-1984  14.49  PROGRAM 214
      5.500   16.0677
  20.959  4.2384     584 .
  26.742  3.3335    3198 .
  29.509  3.0270      54
  36.648  2.4520     254 .
  39.566  2.2777     182 .
  40.415  2.2318     128
  42.551  2.1245     148 .
  45.810  1.9807      82 .
  50.228  1.8164     302 ).
  50.325  1.8131     136
  54.958  1.6707      92
  55.105  1.6666      82
  60.028  1.5411     196 .


     65.500    1.4250
A5258+A5259B  11-04-1984  15.09  PROGRAM 214
```



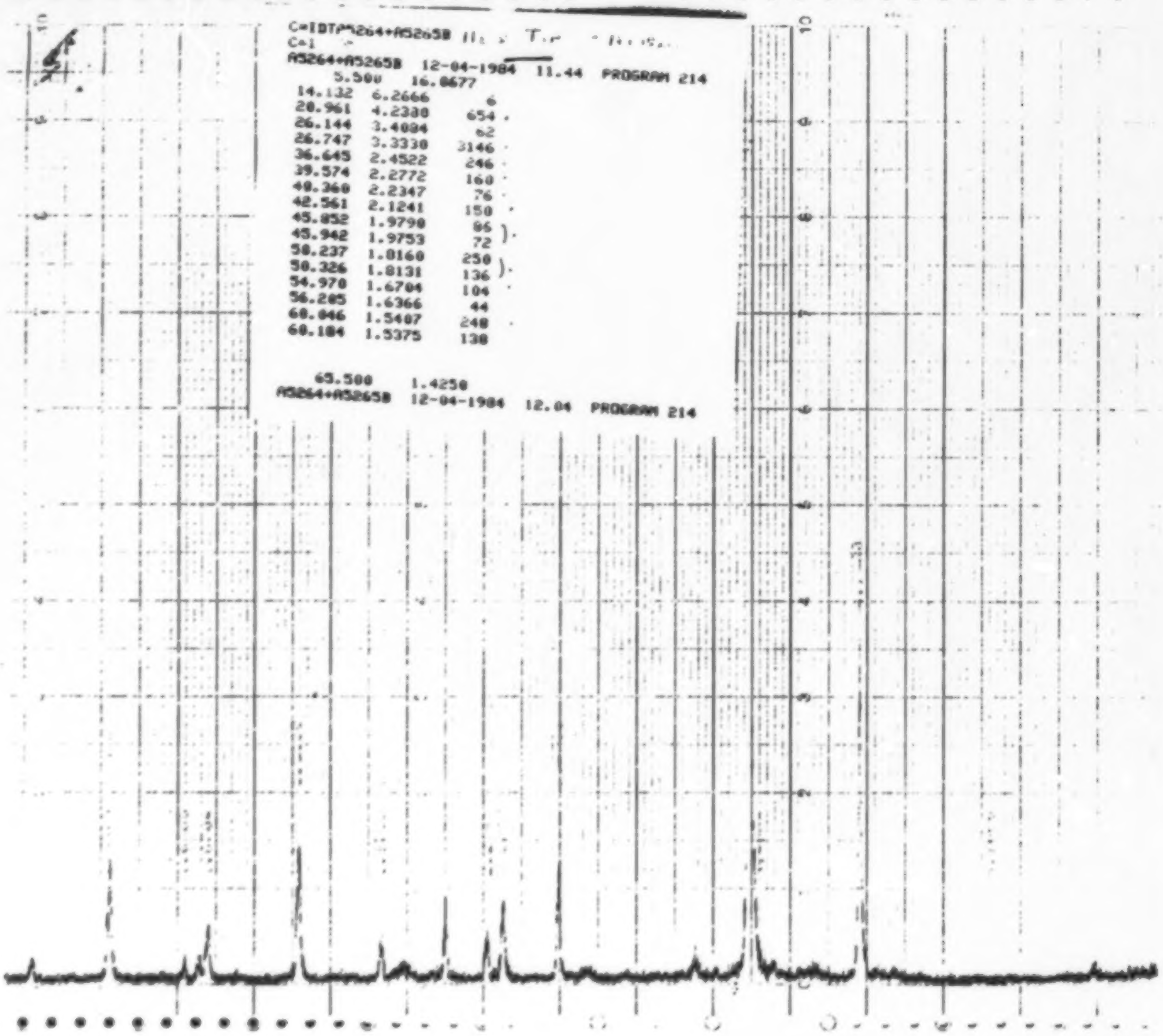
```
C=IDTA5260+A5261B  [illegible]
C=1
A5260+A5261B  12-04-1984  08.36  PROGRAM 214
     5.500   16.0677
 20.961  4.2379    490
 26.746  3.3330   2566
 36.664  2.4510    176
 39.582  2.2768    132
 40.421  2.2315    110
 42.569  2.1237    152
 45.898  1.9771     78
 50.237  1.8161    274
 50.350  1.8123    122
 54.973  1.6703     80
 60.037  1.5409    150
 60.179  1.5376     96
 64.100  1.4527     44


    65.500    1.4250
A5260+A5261B  12-04-1984  08.56  PROGRAM 214
```



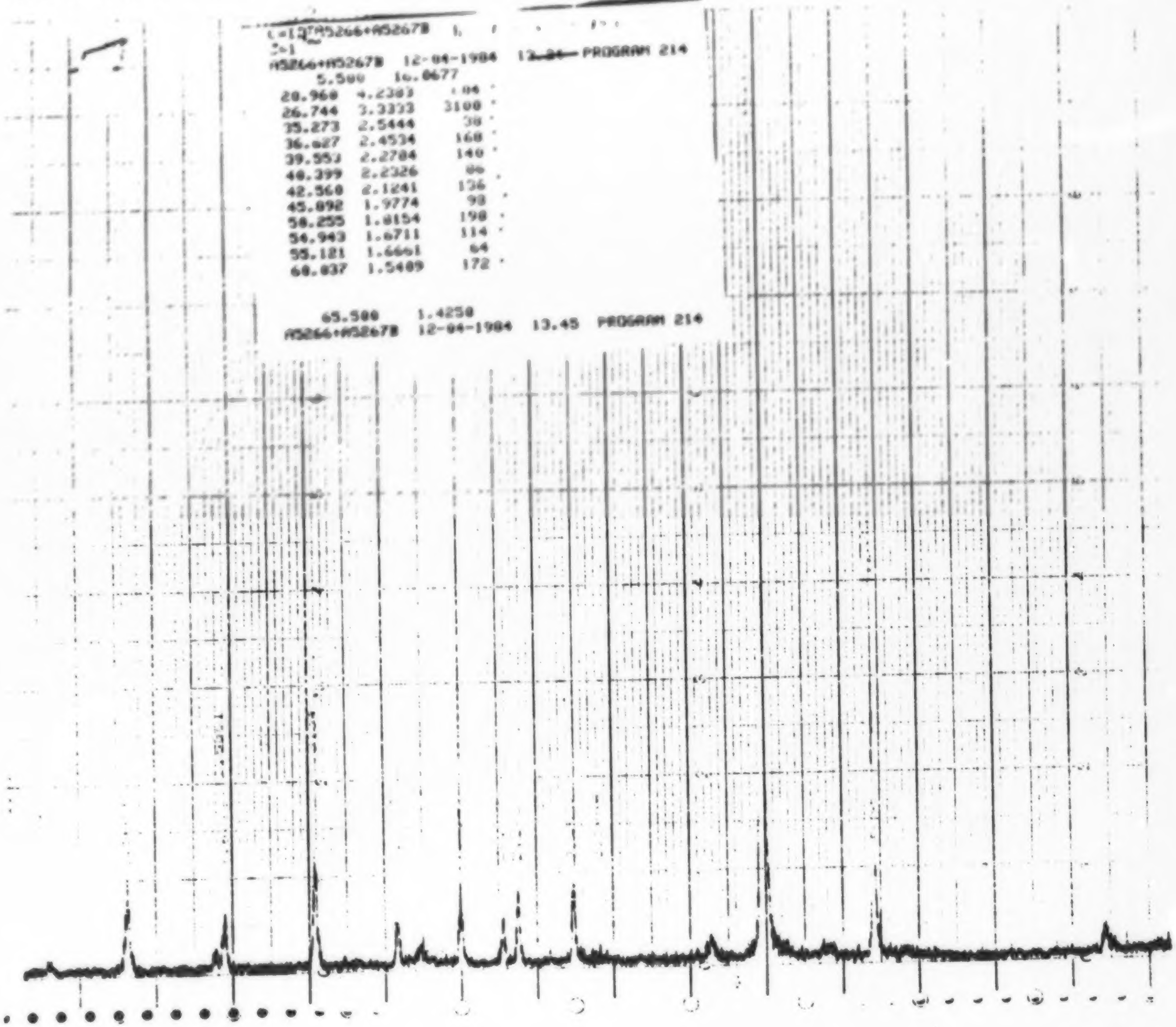
```
A5262+A5263B
C#1
A5262+A5263B  12-04-1984  10.11  PROGRAM 214
     5.500   16.0677
 20.927  4.2448     552 .
 26.722  3.3360    2478 .
 29.324  3.0457      56
 29.510  3.0269      62
 35.182  2.5508      46
 36.623  2.4536     186 .
 39.561  2.2780     158 .
 40.380  2.2336      98 .
 42.523  2.1259     132 .
 45.849  1.9791      68 ).
 45.944  1.9752      62 )
 50.202  1.8172     264 ) .
 50.336  1.8127     168 )
 54.924  1.6716      92 ) .
 55.062  1.6678      74 )
 55.309  1.6587      62
 60.011  1.5415     192 .
 64.091  1.4529      48 .

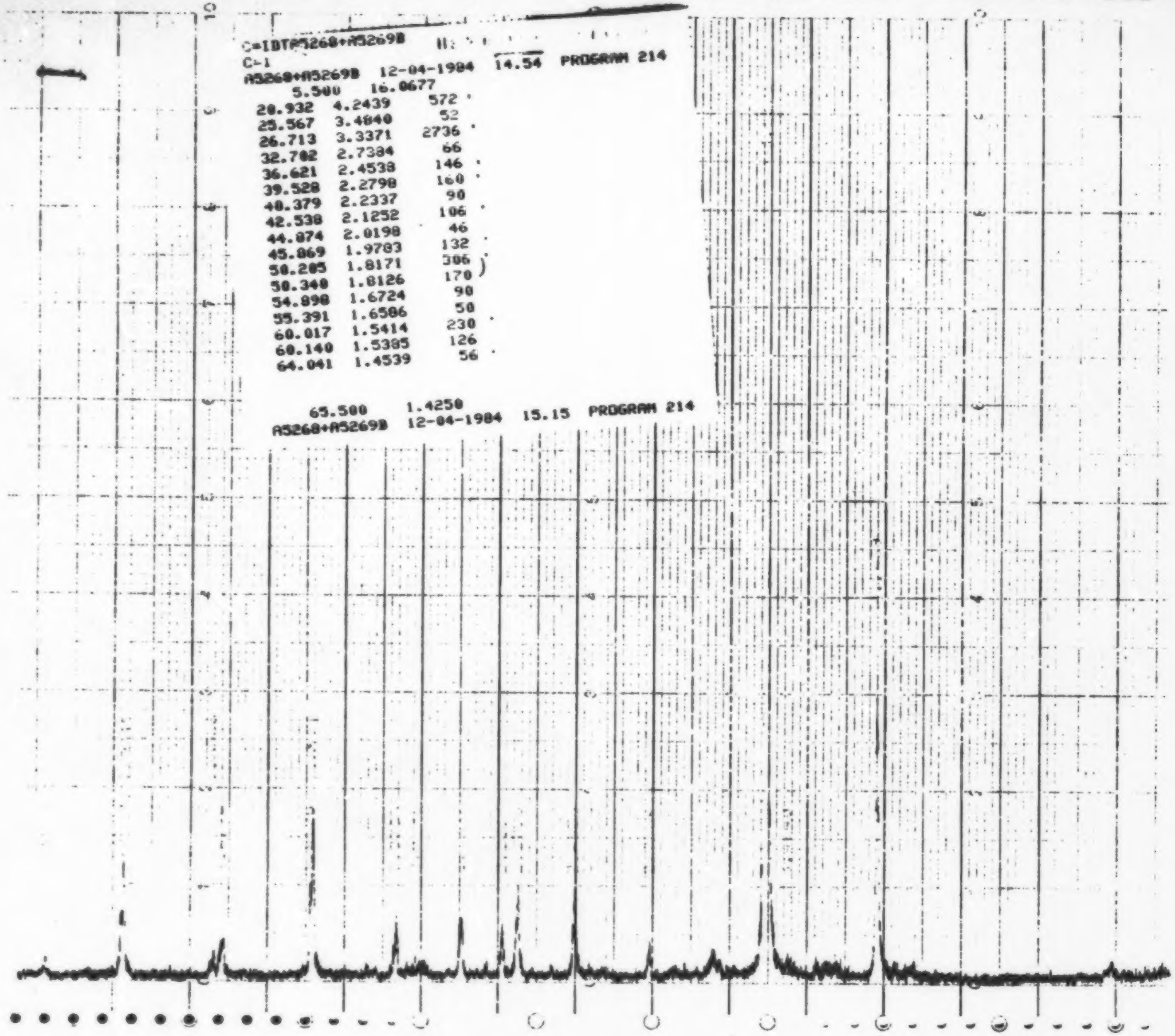
     65.500    1.4250
A5262+A5263B  12-04-1984  10.32  PROGRAM 214
```



```
C=IDT?5264+A5265B
C=1
A5264+A5265B  12-04-1984  11.44  PROGRAM 214
      5.500    16.0677
  14.132   6.2666        6
  20.961   4.2330      654 .
  26.144   3.4084       62
  26.747   3.3330     3146 .
  36.645   2.4522      246 .
  39.574   2.2772      160 .
  40.360   2.2347       76 .
  42.561   2.1241      150  .
  45.852   1.9790       86 ).
  45.942   1.9753       72
  50.237   1.8160      250 ).
  50.326   1.8131      136
  54.970   1.6704      104  .
  56.205   1.6366       44
  60.046   1.5407      248  .
  60.184   1.5375      130

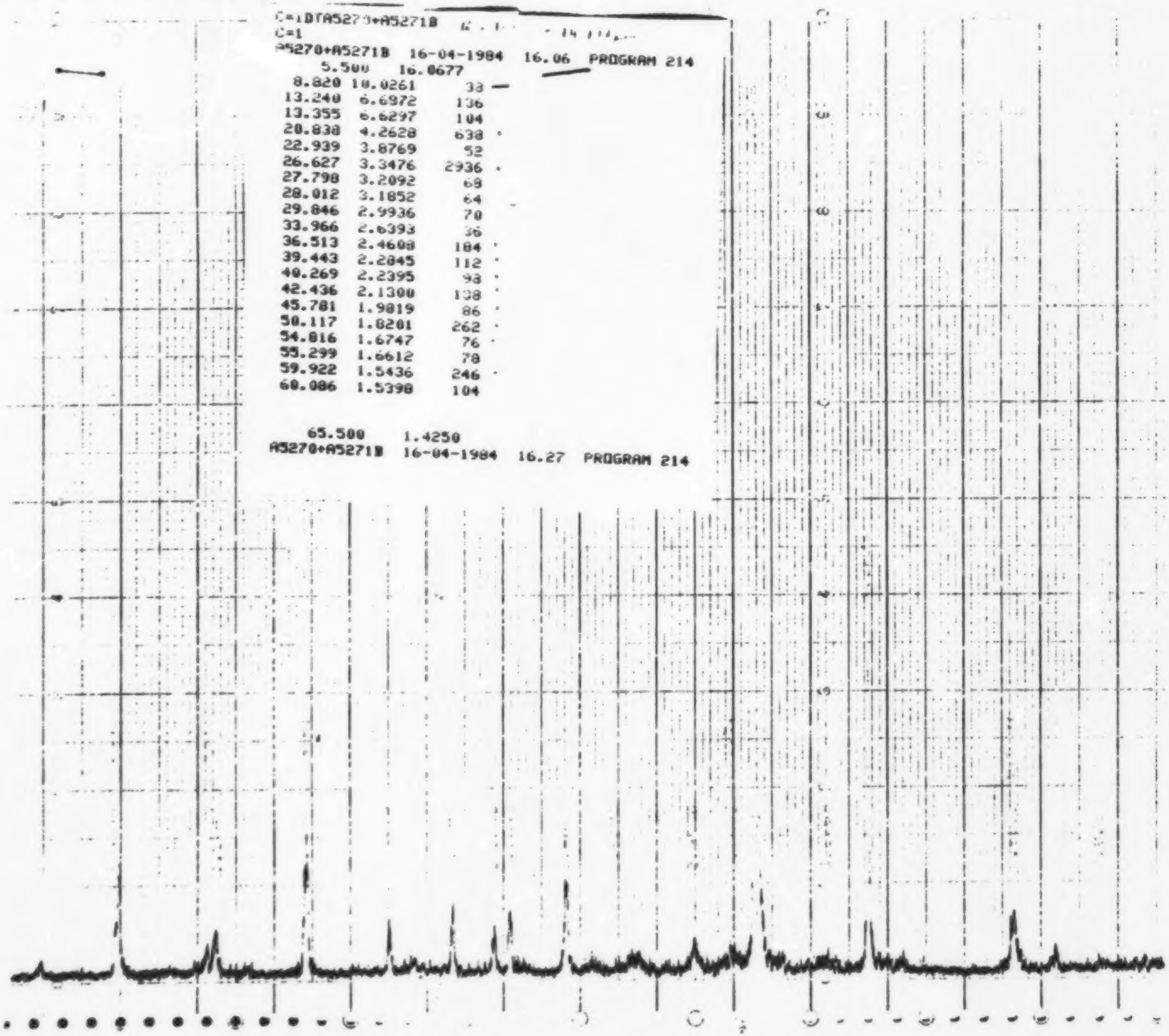
      65.500    1.4250
A5264+A5265B  12-04-1984   12.04  PROGRAM 214
```





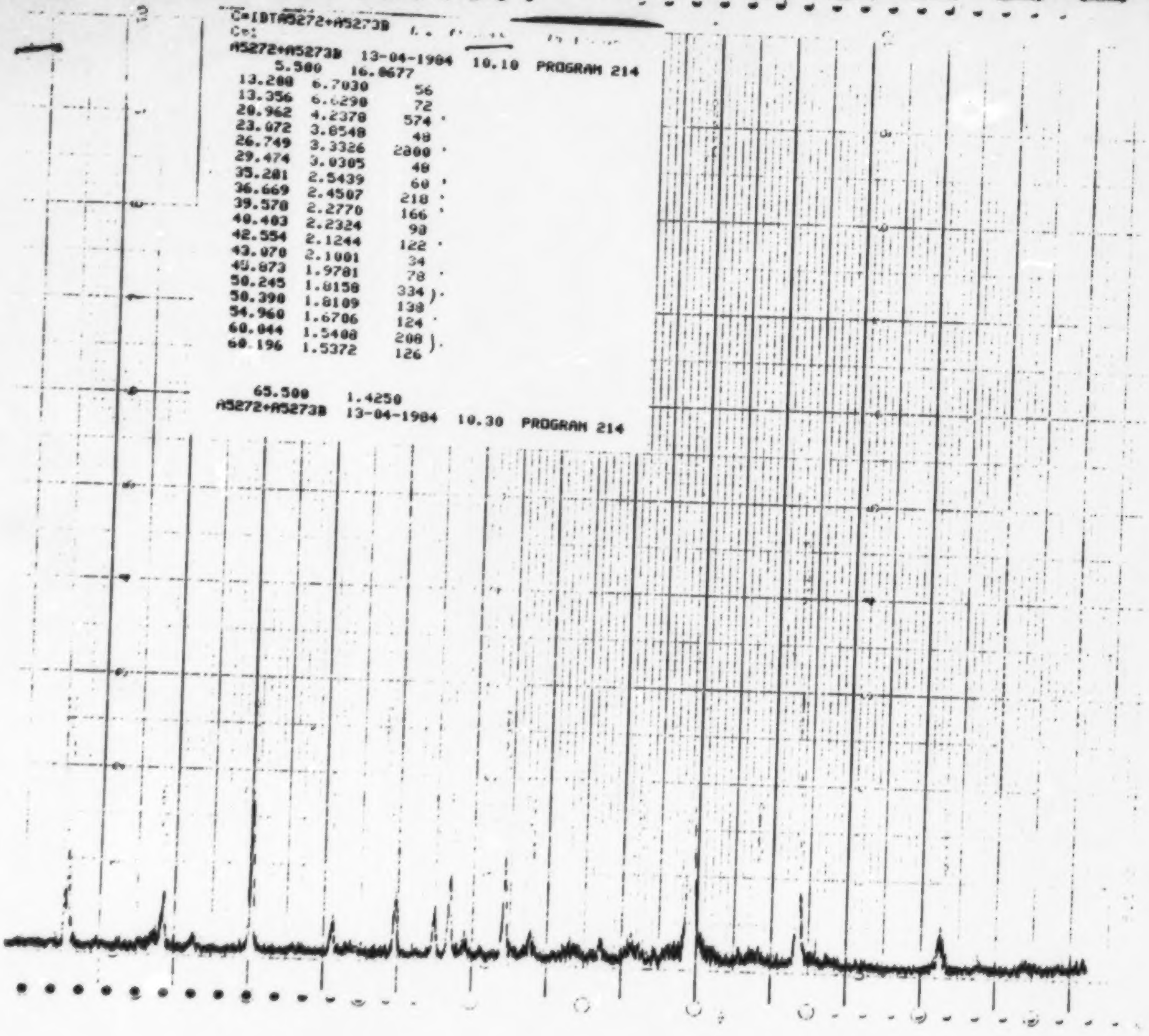
```
C=IBTA5268+A5269B    II:
C-1
A5268+A5269B   12-04-1984   14.54   PROGRAM 214
      5.500    16.0677
  20.932    4.2439      572
  25.567    3.4840       52
  26.713    3.3371     2736
  32.702    2.7384       66
  36.621    2.4538      146
  39.528    2.2798      160
  40.379    2.2337       90
  42.538    2.1252      106
  44.874    2.0198       46
  45.869    1.9783      132
  50.205    1.8171      306 )
  50.340    1.8126      170
  54.898    1.6724       90
  55.391    1.6586       50
  60.017    1.5414      230
  60.140    1.5385      126
  64.041    1.4539       56

      65.500     1.4250
  A5268+A5269B  12-04-1984   15.15   PROGRAM 214
```



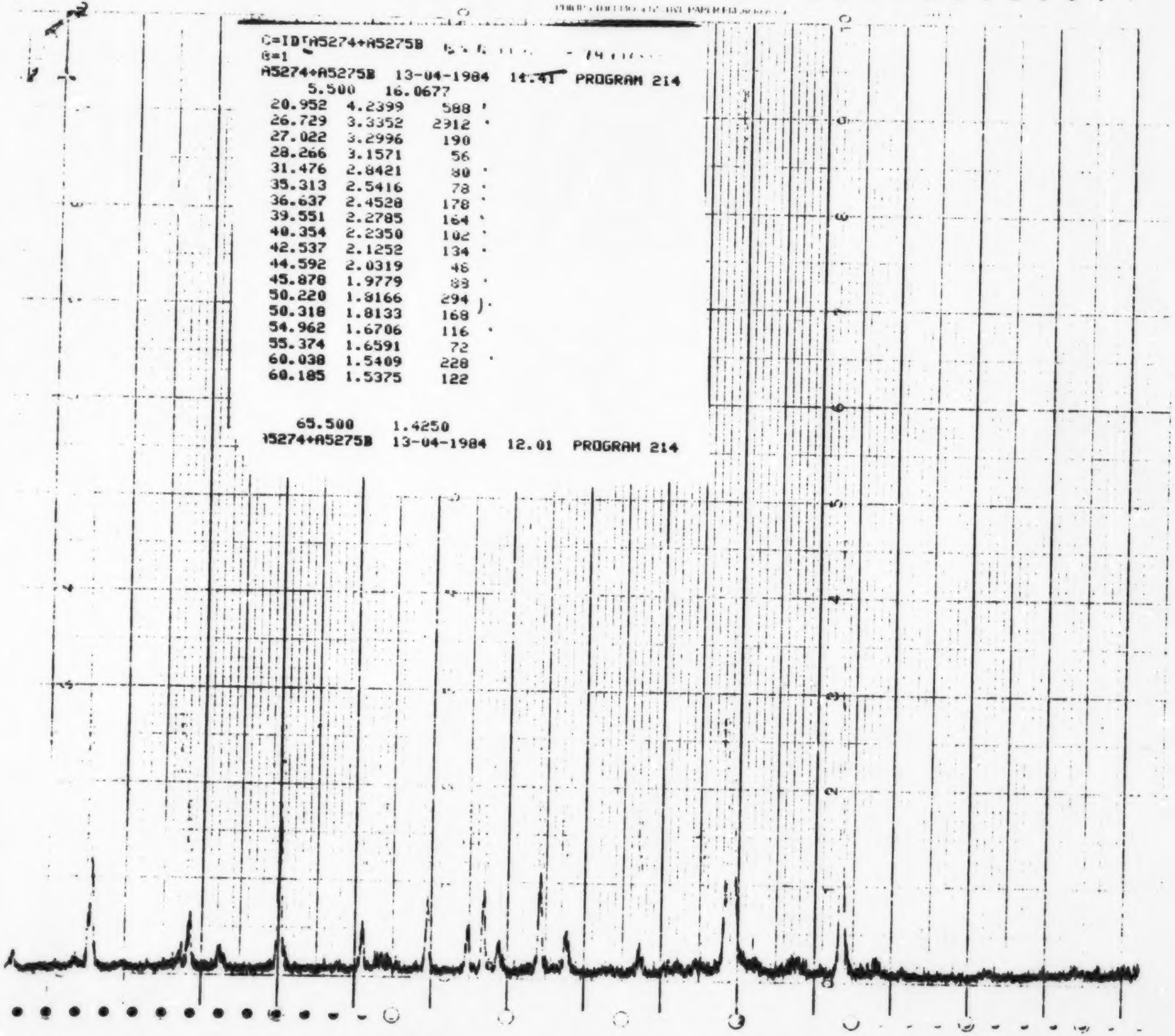
```
C=1DTA5270+A5271B
C=1
A5270+A5271B  16-04-1984  16.06  PROGRAM 214
      5.500   16.0677
   8.820 10.0261       38
  13.240  6.6972      136
  13.355  6.6297      104
  20.838  4.2628      638
  22.939  3.8769       52
  26.627  3.3476     2936
  27.798  3.2092       68
  28.012  3.1852       64
  29.846  2.9936       70
  33.966  2.6393       36
  36.513  2.4608      184
  39.443  2.2845      112
  40.269  2.2395       98
  42.436  2.1300      138
  45.781  1.9819       86
  50.117  1.8201      262
  54.816  1.6747       76
  55.299  1.6612       78
  59.922  1.5436      246
  60.086  1.5398      104


     65.500     1.4250
A5270+A5271B  16-04-1984  16.27  PROGRAM 214
```



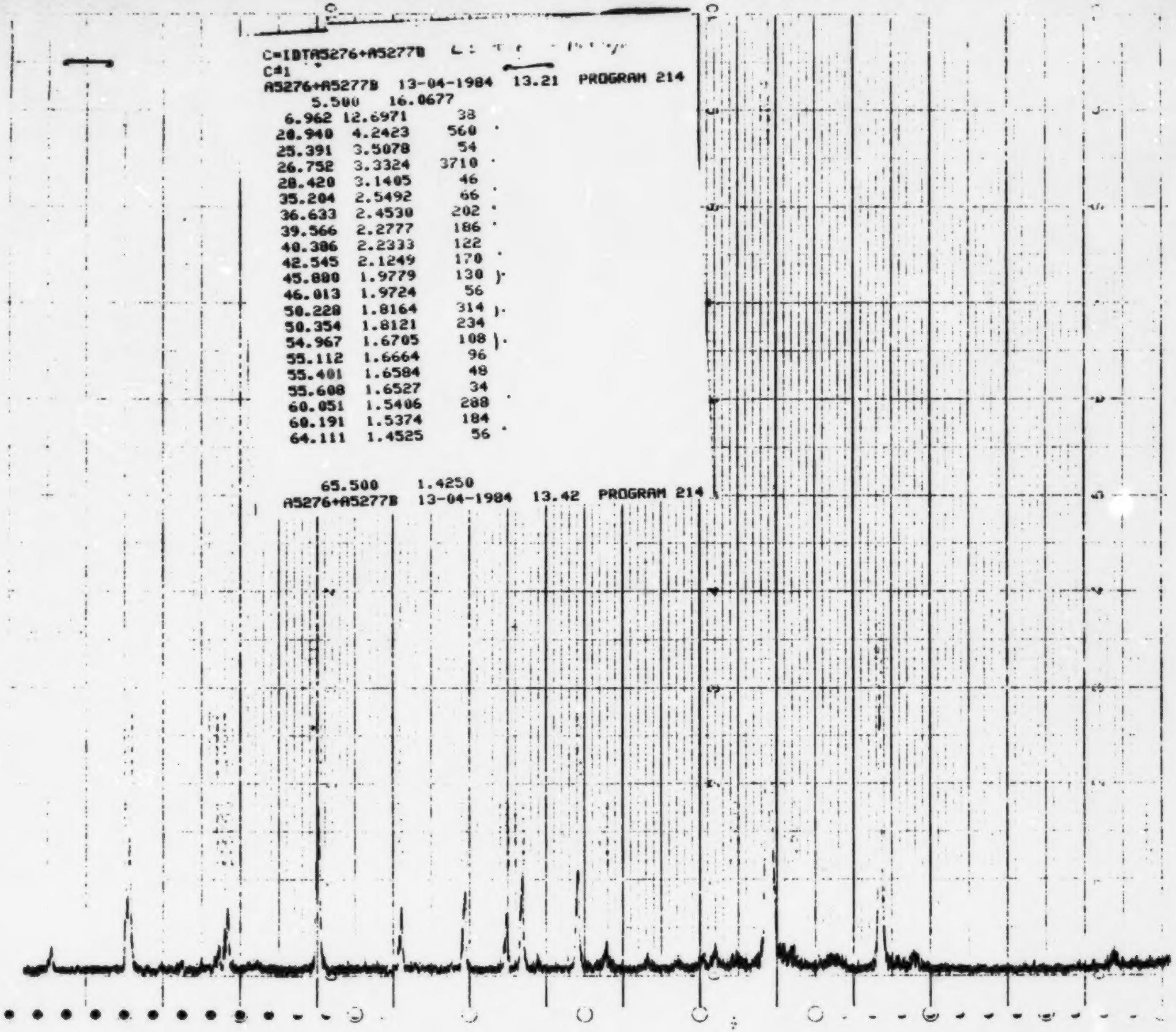
```
C=IDTA5272+A5273B
Ce:
A5272+A5273B  13-04-1984  10.10  PROGRAM 214
      5.500   16.0677
   13.200   6.7030      56
   13.356   6.6290      72
   20.962   4.2370     574 .
   23.072   3.8540      48
   26.749   3.3326    2800 .
   29.474   3.0305      48
   35.201   2.5439      60 .
   36.669   2.4507     218 .
   39.570   2.2770     166 .
   40.403   2.2324      98
   42.554   2.1244     122 .
   43.070   2.1001      34
   45.873   1.9781      78 .
   50.245   1.8150     334 ).
   50.390   1.8109     138
   54.960   1.6706     124 .
   60.044   1.5400     208 ).
   60.196   1.5372     126

     65.500     1.4250
A5272+A5273B  13-04-1984  10.30  PROGRAM 214
```



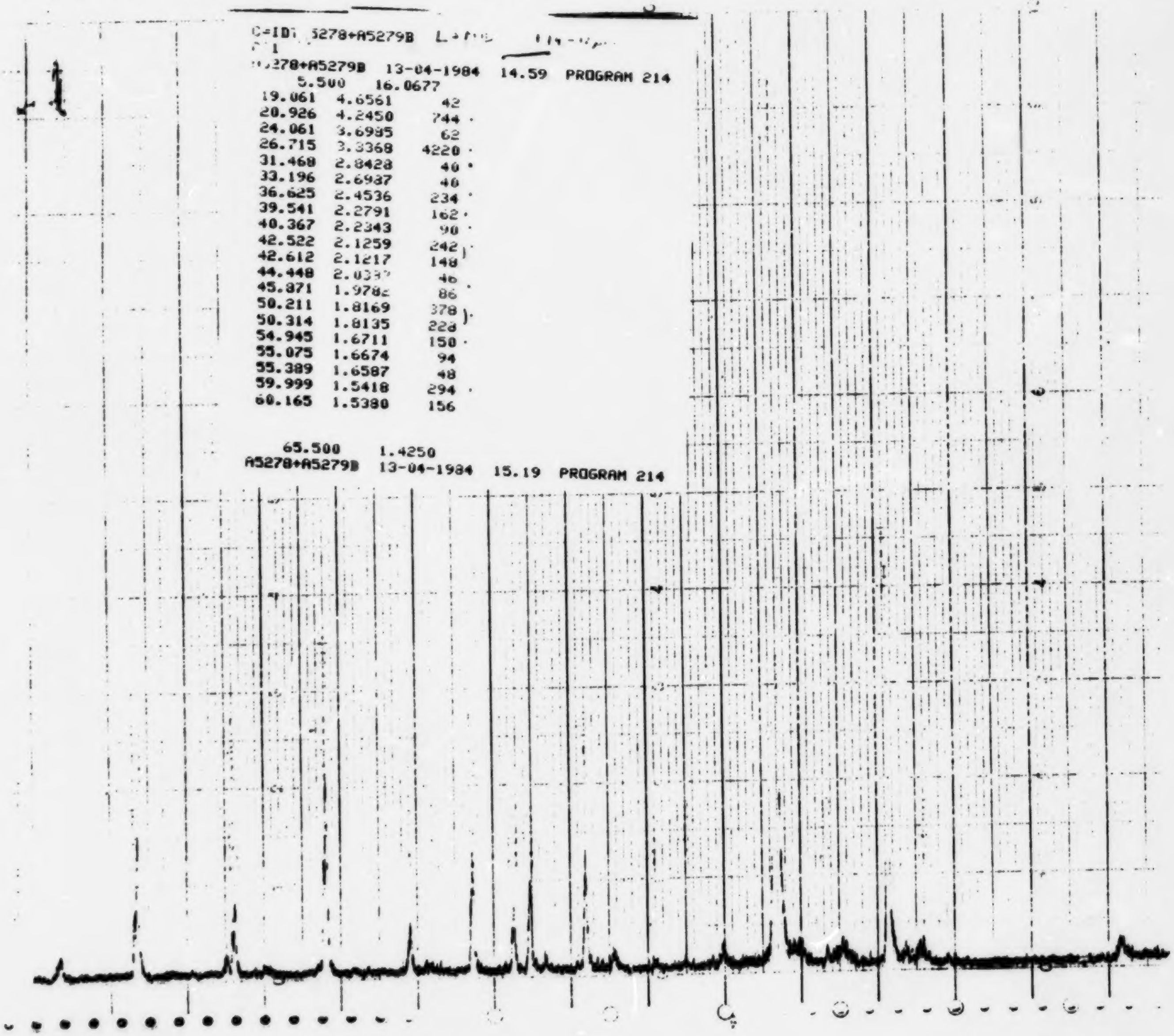
```
C=ID:A5274+A5275B
B=1
A5274+A5275B  13-04-1984  14.41  PROGRAM 214
      5.500    16.0677
  20.952   4.2399      588 '
  26.729   3.3352     2312 .
  27.022   3.2996      190
  28.266   3.1571       56
  31.476   2.8421       80 .
  35.313   2.5416       78 .
  36.637   2.4528      178 .
  39.551   2.2785      164 .
  40.354   2.2350      102 .
  42.537   2.1252      134 .
  44.592   2.0319       46
  45.878   1.9779       88 .
  50.220   1.8166      294 ).
  50.318   1.8133      168
  54.962   1.6706      116  .
  55.374   1.6591       72
  60.038   1.5409      228  .
  60.185   1.5375      122


     65.500     1.4250
A5274+A5275B  13-04-1984  12.01  PROGRAM 214
```



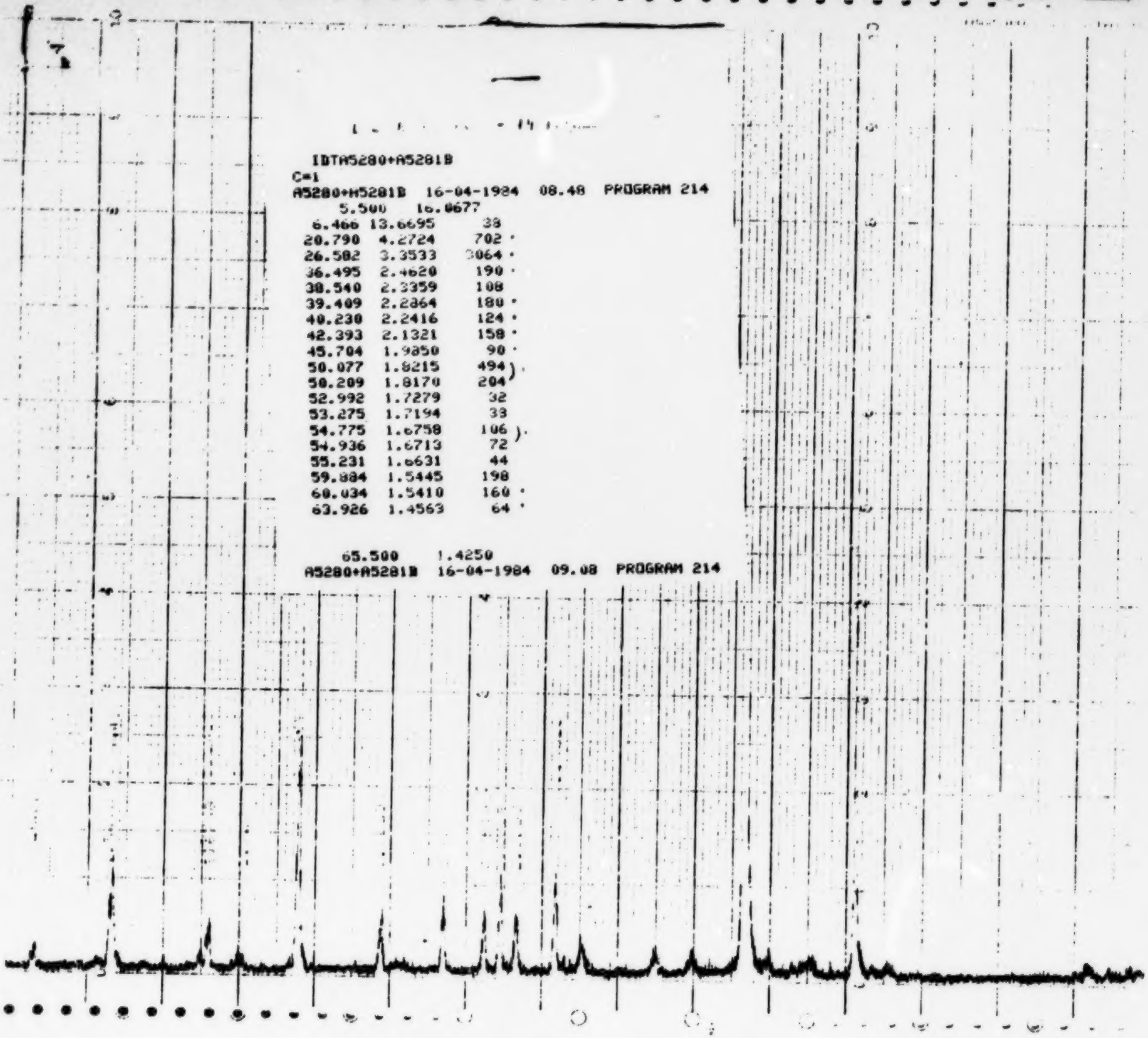
```
C=IDTA5276+A5277B
C#1
A5276+A5277B  13-04-1984  13.21  PROGRAM 214
     5.500   16.0677
   6.962 12.6971      38
  20.940  4.2423     560 .
  25.391  3.5078      54
  26.752  3.3324    3710 .
  28.420  3.1405      46
  35.204  2.5492      66 .
  36.633  2.4530     202 .
  39.566  2.2777     186 .
  40.386  2.2333     122
  42.545  2.1249     170 .
  45.880  1.9779     130 ).
  46.013  1.9724      56
  50.228  1.8164     314 ).
  50.354  1.8121     234
  54.967  1.6705     108 ).
  55.112  1.6664      96
  55.401  1.6584      48
  55.608  1.6527      34
  60.051  1.5406     288 .
  60.191  1.5374     184
  64.111  1.4525      56 .


     65.500     1.4250
  A5276+A5277B  13-04-1984  13.42  PROGRAM 214
```



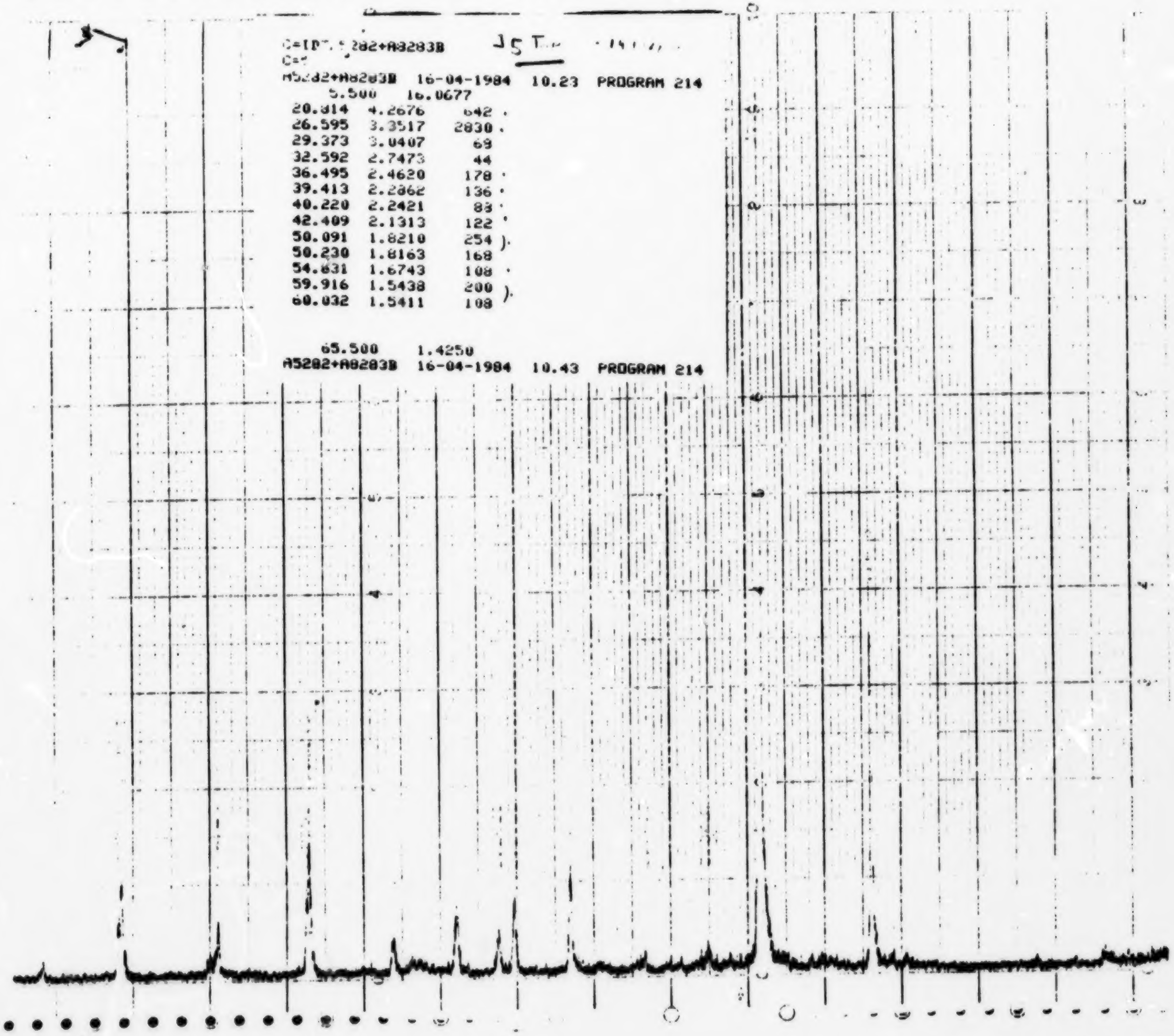
```
C=ID: 5278+A5279B  [illegible]
  1
  278+A5279B  13-04-1984  14.59  PROGRAM 214
     5.500   16.0677
  19.061  4.6561      42
  20.926  4.2450     744 .
  24.061  3.6985      62
  26.715  3.3368    4220 .
  31.468  2.8428      40 .
  33.196  2.6987      40
  36.625  2.4536     234 .
  39.541  2.2791     162 .
  40.367  2.2343      90 .
  42.522  2.1259     242 ).
  42.612  2.1217     148
  44.448  2.033[illegible]      46 .
  45.871  1.9782      86
  50.211  1.8169     378 ).
  50.314  1.8135     228
  54.945  1.6711     150 .
  55.075  1.6674      94
  55.389  1.6587      48
  59.999  1.5418     294 .
  60.165  1.5380     156


     65.500     1.4250
A5278+A5279B  13-04-1984  15.19  PROGRAM 214
```



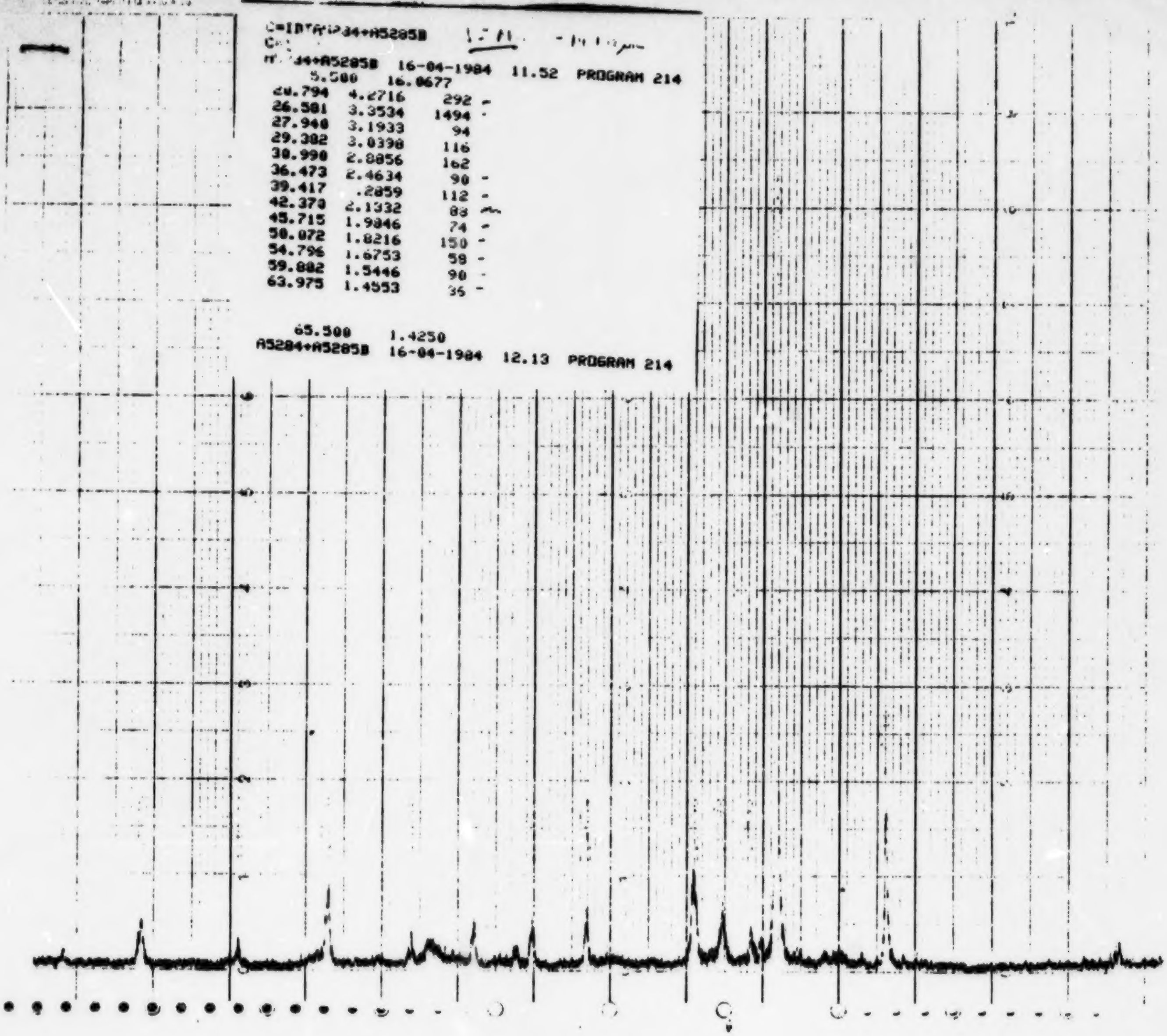
```
  IDTA5280+A5281B
C=1
A5280+H5281B  16-04-1984  08.48  PROGRAM 214
     5.500   16.0677
   6.466 13.6695      38
  20.790  4.2724     702 ·
  26.582  3.3533    3064 ·
  36.495  2.4620     190 ·
  38.540  2.3359     108
  39.409  2.2864     180 ·
  40.230  2.2416     124 ·
  42.393  2.1321     158 ·
  45.704  1.9850      90 ·
  50.077  1.8215     494) ·
  50.209  1.8170     204
  52.992  1.7279      32
  53.275  1.7194      33
  54.775  1.6758     106 ) ·
  54.936  1.6713      72
  55.231  1.6631      44
  59.884  1.5445     198
  60.034  1.5410     160 ·
  63.926  1.4563      64 ·


     65.500     1.4250
 A5280+A5281B  16-04-1984  09.08  PROGRAM 214
```



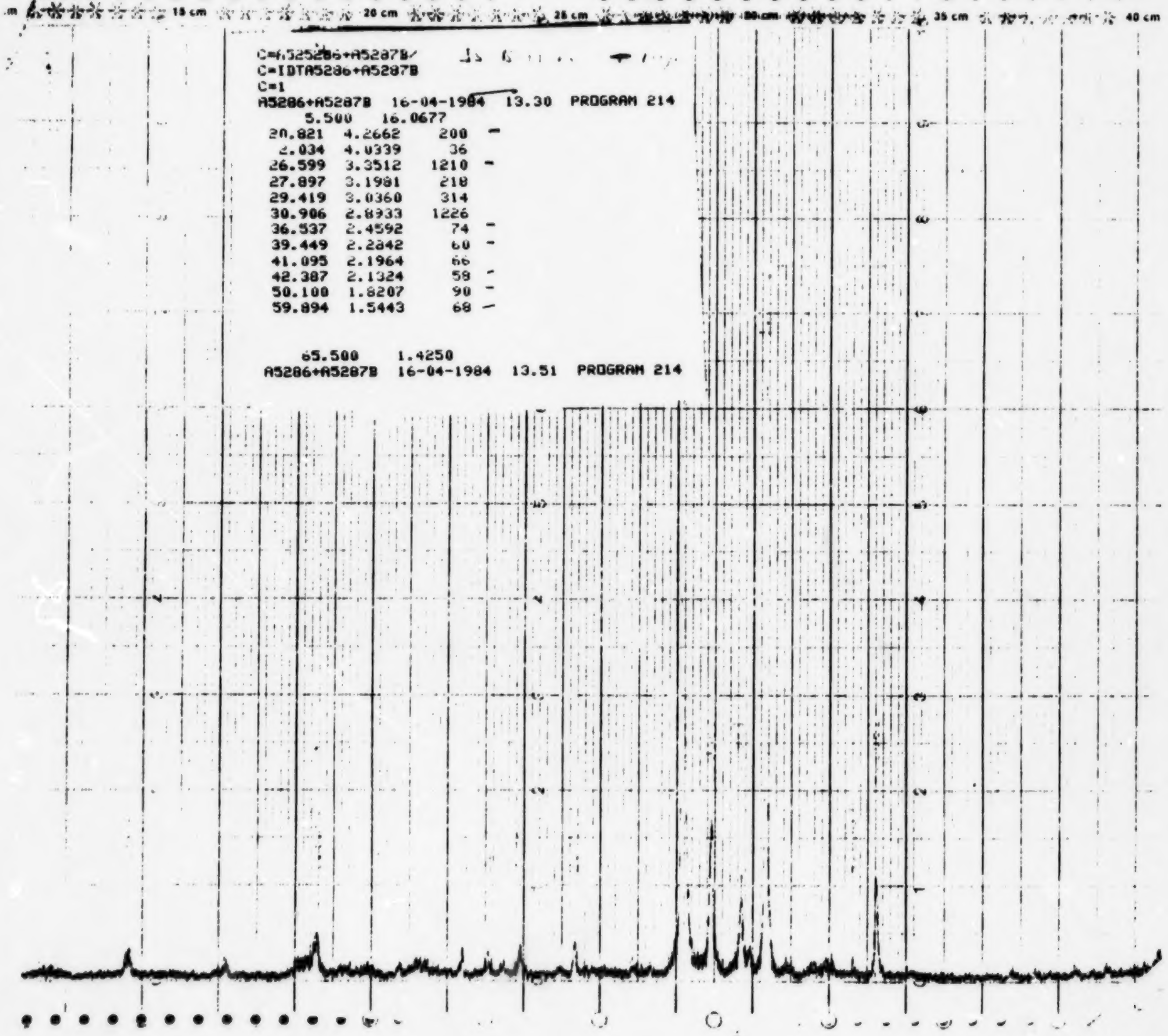
```
C=ID[illegible]282+A8283B        J5 T
C=
A5282+A8283B  16-04-1984  10.23  PROGRAM 214
     5.500   16.0677
 20.814  4.2676     642 .
 26.595  3.3517    2830 .
 29.373  3.0407      69
 32.592  2.7473      44
 36.495  2.4620     178 ·
 39.413  2.2862     136 ·
 40.220  2.2421      83 ·
 42.409  2.1313     122 ·
 50.091  1.8210     254 ).
 50.230  1.8163     168
 54.831  1.6743     108 ·
 59.916  1.5438     200 ).
 60.032  1.5411     108


    65.500    1.4250
A5282+A8283B  16-04-1984  10.43  PROGRAM 214
```



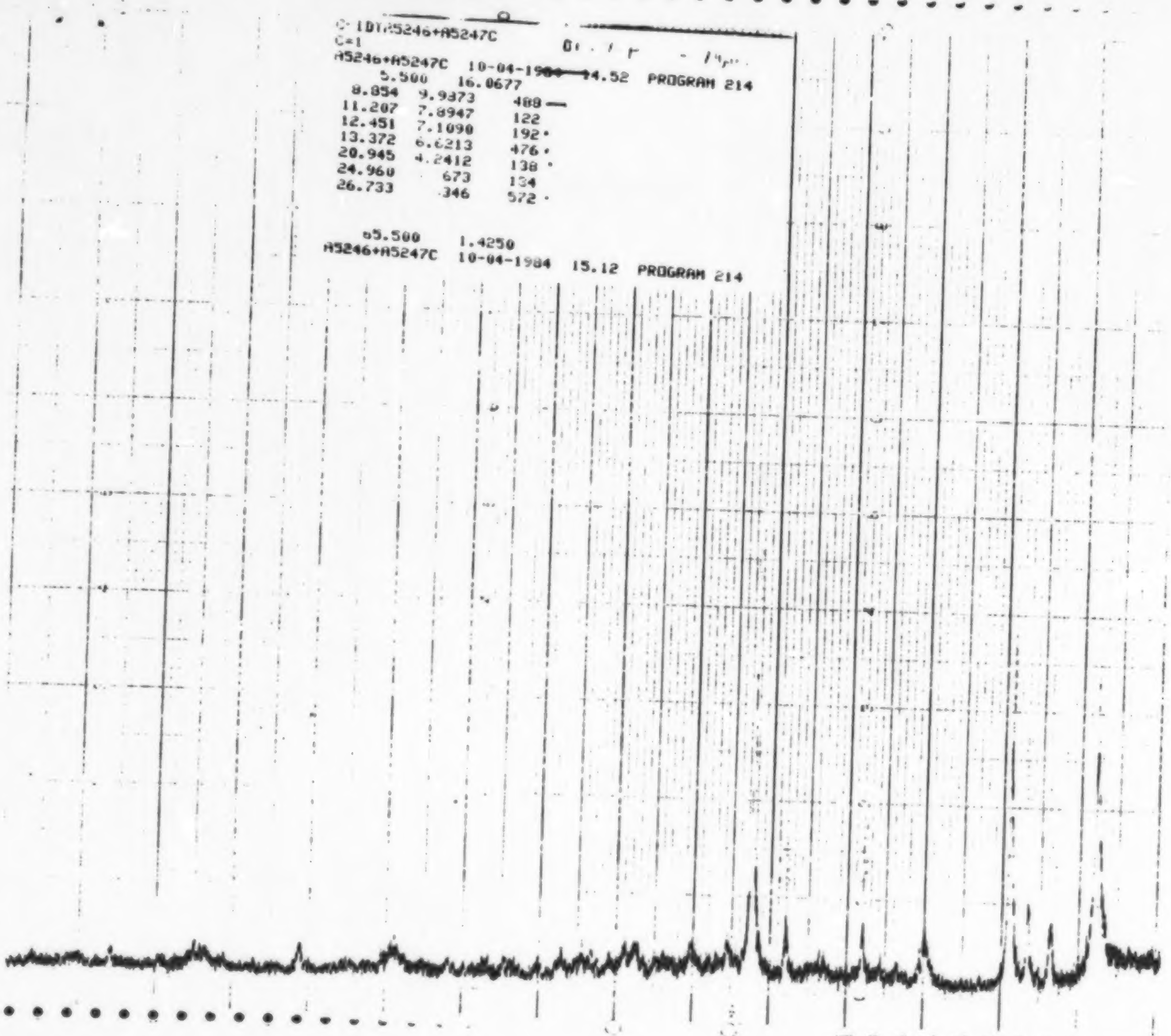
```
C=IBTA?P34+A5285B
C:
M  34+A5285B  16-04-1984  11.52  PROGRAM 214
     5.500   16.0677
  20.794   4.2716     292
  26.581   3.3534    1494
  27.940   3.1933      94
  29.382   3.0398     116
  30.990   2.8856     162
  36.473   2.4634      90
  39.417    .2859     112
  42.370   2.1332      88
  45.715   1.9846      74
  50.072   1.8216     150
  54.796   1.6753      58
  59.882   1.5446      90
  63.975   1.4553      36

     65.500    1.4250
A5284+A5285B  16-04-1984  12.13  PROGRAM 214
```



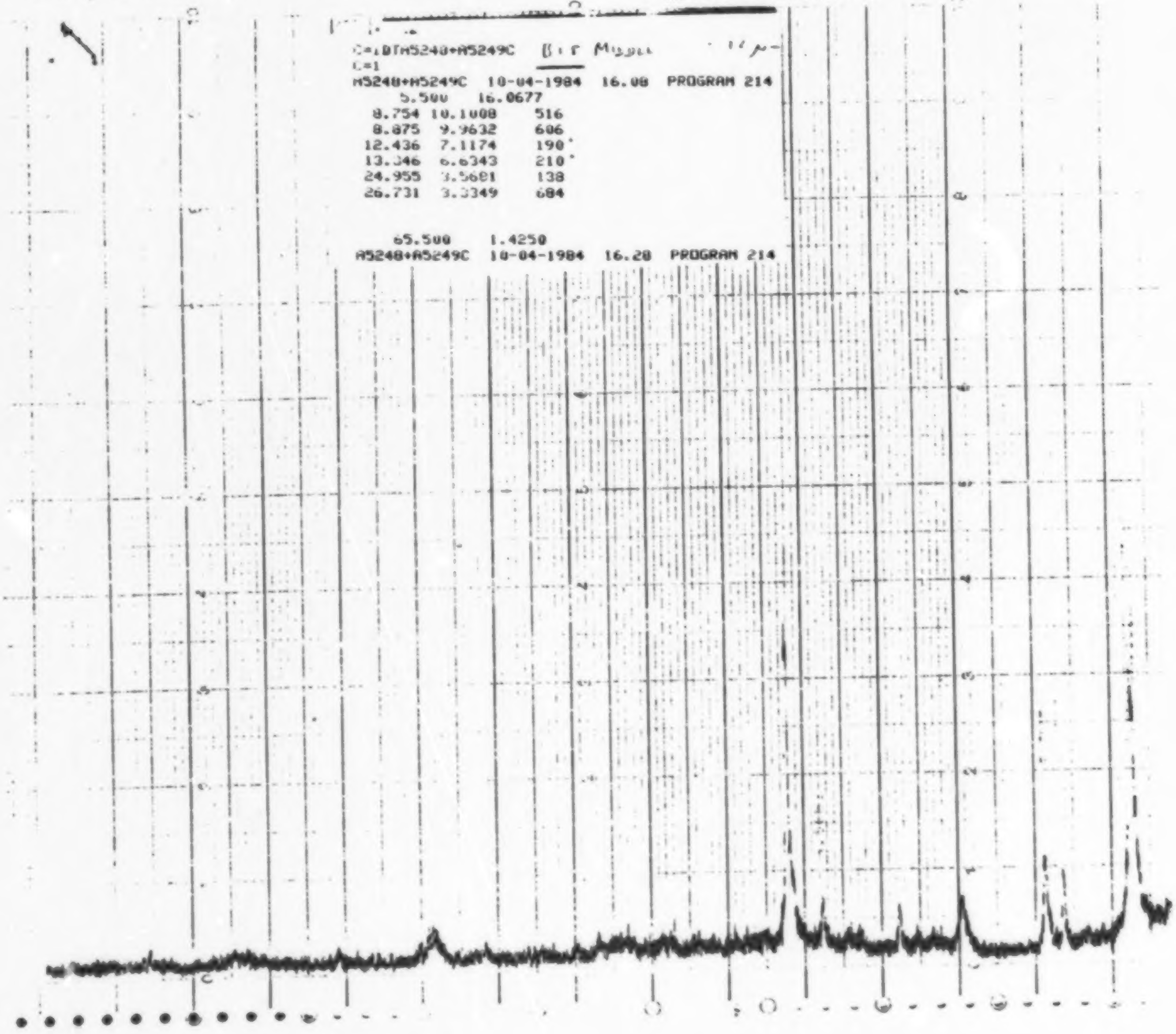
```
C=A525286+A5287B/
C=IDTA5286+A5287B
C=1
A5286+A5287B  16-04-1984  13.30  PROGRAM 214
     5.500   16.0677
 20.821  4.2662     200
  2.034  4.0339      36
 26.599  3.3512    1210
 27.897  3.1981     218
 29.419  3.0360     314
 30.906  2.8933    1226
 36.537  2.4592      74
 39.449  2.2842      60
 41.095  2.1964      66
 42.387  2.1324      58
 50.100  1.8207      90
 59.894  1.5443      68


    65.500    1.4250
 A5286+A5287B  16-04-1984  13.51  PROGRAM 214
```



```
C-1DT:A5246+A5247C
C=1
A5246+A5247C  10-04-1984  14.52  PROGRAM 214
     5.500   16.0677
  8.854   9.9373      488
 11.207   7.8947      122
 12.451   7.1090      192
 13.372   6.6213      476
 20.945   4.2412      138
 24.960      673      134
 26.733      346      572

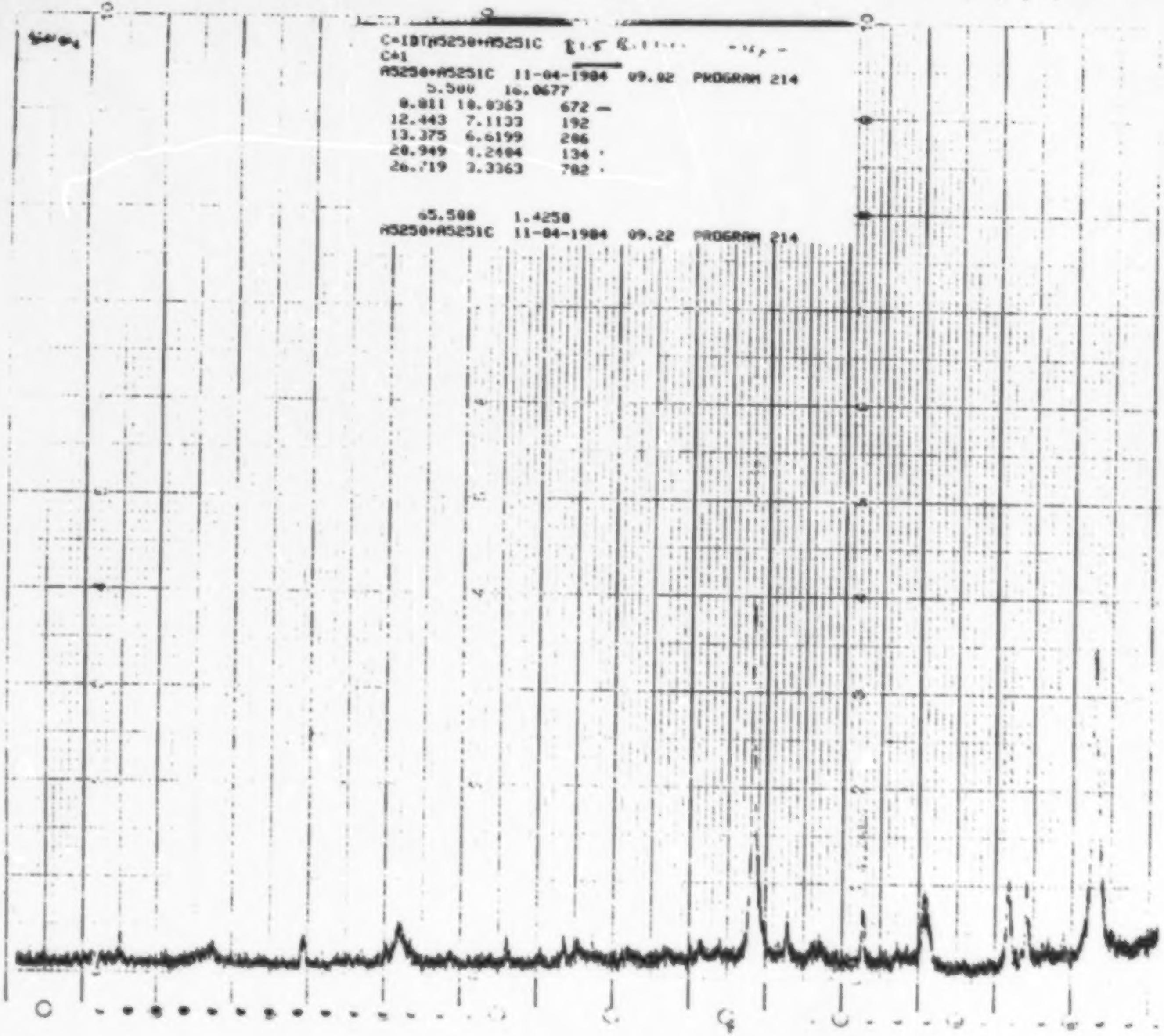
    65.500      1.4250
A5246+A5247C  10-04-1984  15.12  PROGRAM 214
```



```
C=,DTH5240+A5249C
C=1
A5240+A5249C   10-04-1984   16.00   PROGRAM 214
      5.500   16.0677
   8.754 10.1000      516
   8.875  9.9632      606
  12.436  7.1174      190'
  13.346  6.6343      210'
  24.955  3.5601      138
  26.731  3.3349      684

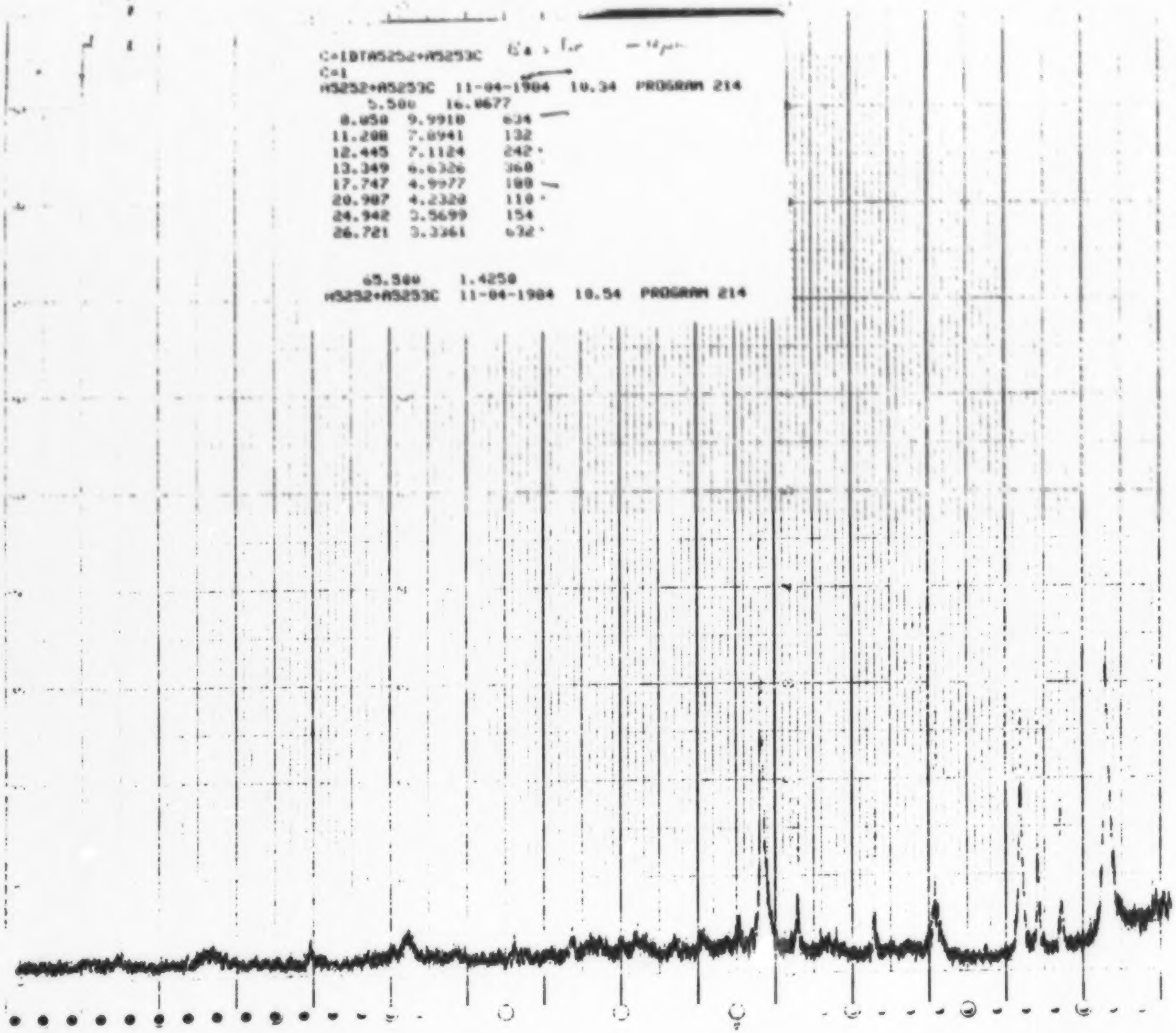

      65.500    1.4250
A5240+A5249C   10-04-1984   16.20   PROGRAM 214
```

B i r M[illegible]



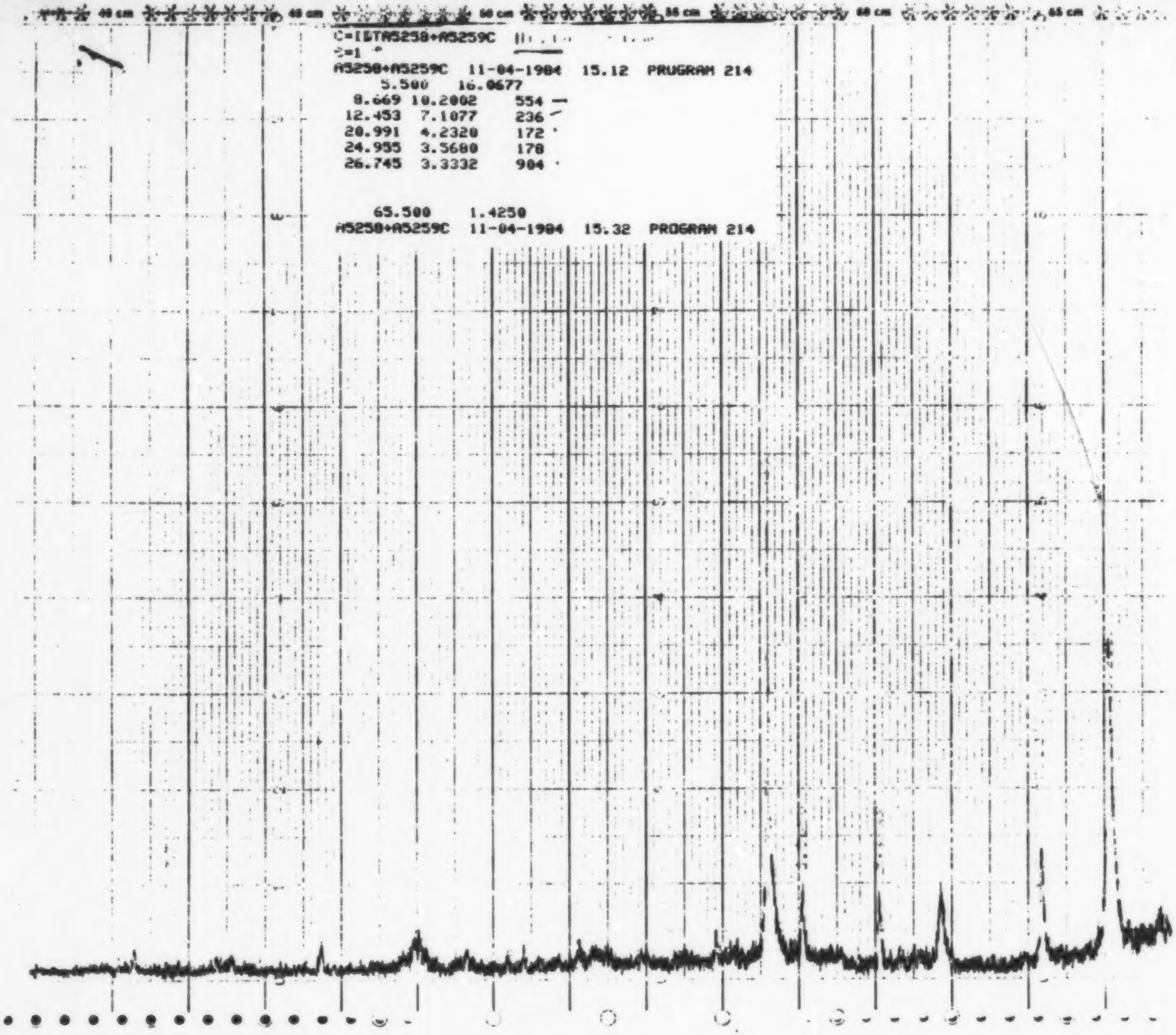
```
C=IDTM5250+M5251C
C#1
M5250+M5251C  11-04-1984  09.02  PROGRAM 214
     5.500   16.0677
  8.811 10.0363    672 —
 12.443  7.1133    192
 13.375  6.6199    206
 20.949  4.2404    134 ·
 26.719  3.3363    702 ·


     65.500    1.4250
M5250+M5251C  11-04-1984  09.22  PROGRAM 214
```



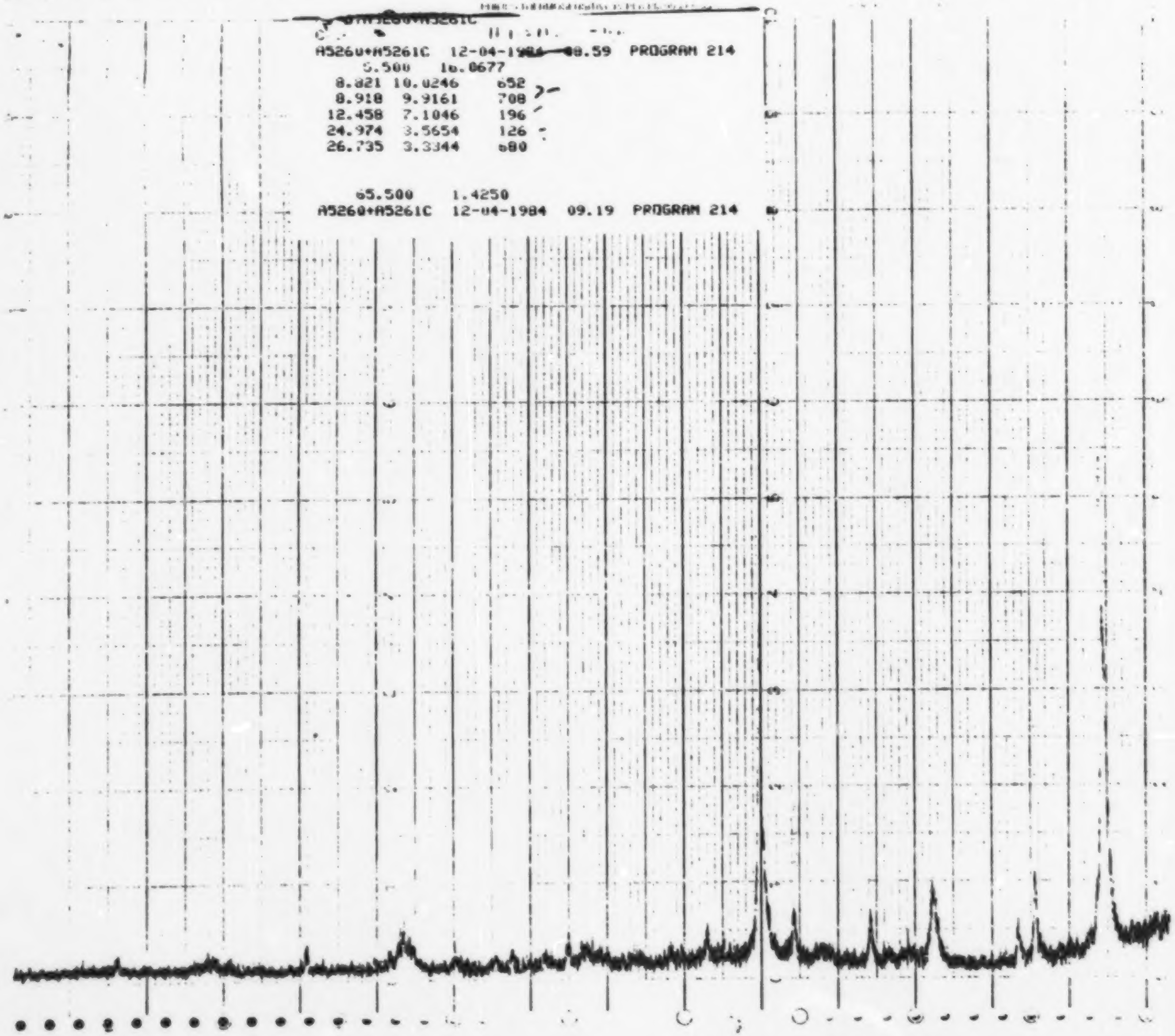
```
C=IDTA5252+A5253C
C=1
A5252+A5253C  11-04-1984  10.34  PROGRAM 214
     5.500   16.0677
  8.850   9.9910     634
 11.200   7.8941     132
 12.445   7.1124     242
 13.349   6.6326     360
 17.747   4.9977     100
 20.987   4.2320     110
 24.942   3.5699     154
 26.721   3.3361     632


     65.500    1.4250
A5252+A5253C  11-04-1984  10.54  PROGRAM 214
```



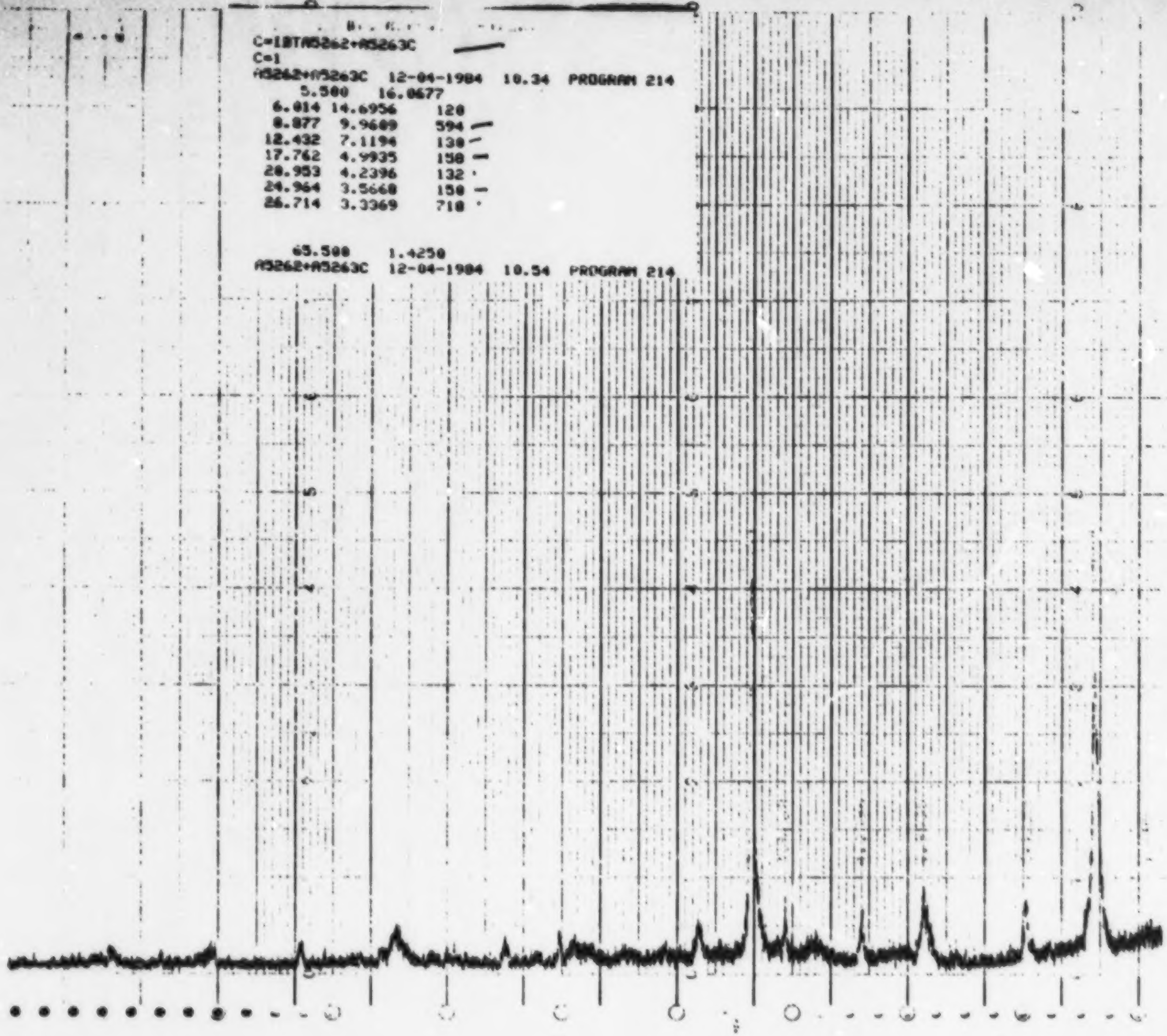
```
C=IDTA5258+A5259C
Ç=1
A5258+A5259C  11-04-1984  15.12  PRUGRAM 214
     5.500   16.0677
   8.669 10.2002      554
  12.453  7.1077      236
  20.991  4.2320      172
  24.955  3.5680      178
  26.745  3.3332      904


    65.500    1.4250
A5258+A5259C  11-04-1984  15.32  PROGRAM 214
```



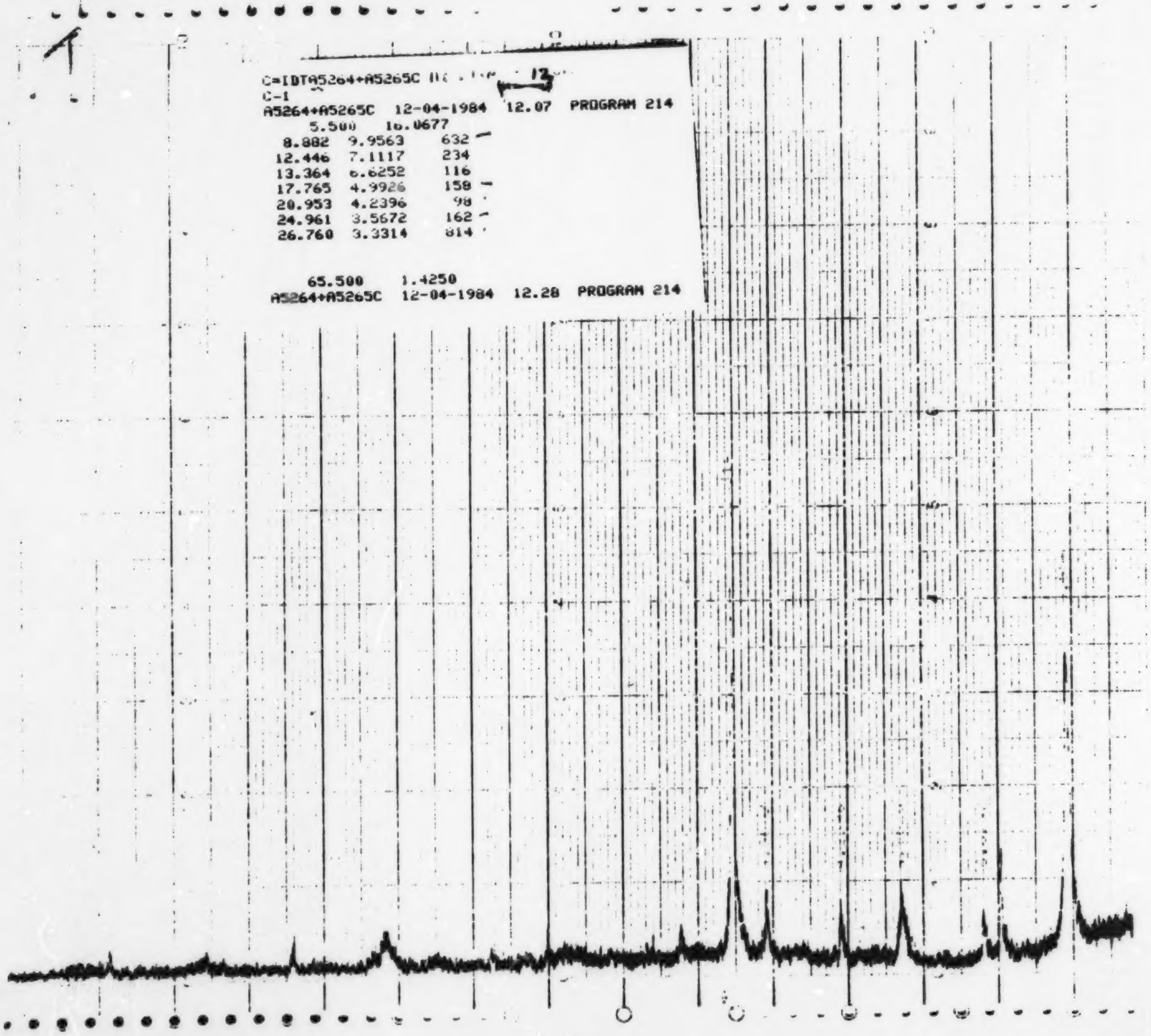
```
A5260+A5261C  12-04-1984  08.59  PROGRAM 214
     5.500   16.0677
   8.821  10.0246     652
   8.918   9.9161     708
  12.458   7.1046     196
  24.974   3.5654     126
  26.735   3.3344     680


     65.500    1.4250
A5260+A5261C  12-04-1984  09.19  PROGRAM 214
```



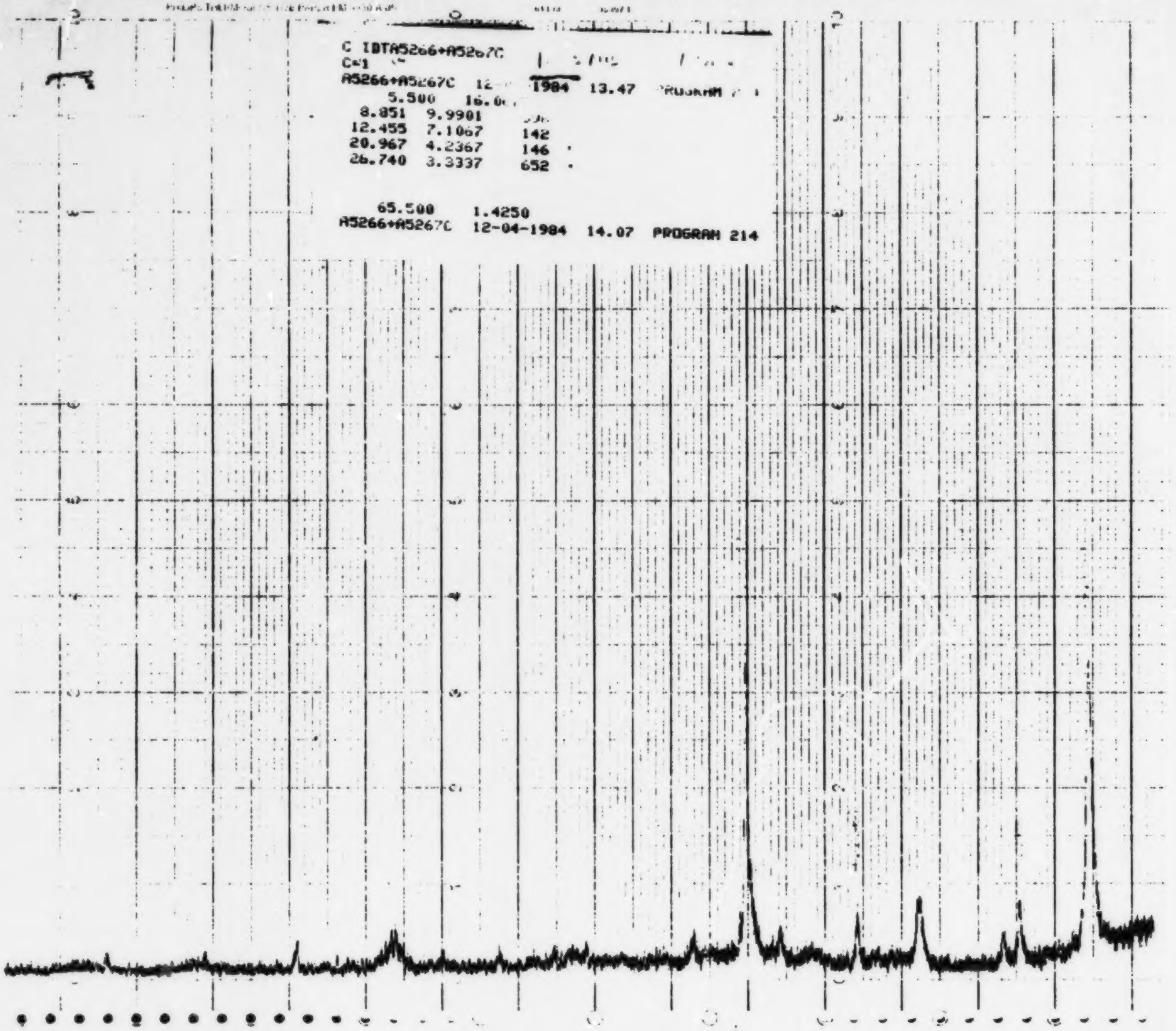
```
C=10TA5262+A5263C
C=1
A5262+A5263C  12-04-1984  10.34  PROGRAM 214
     5.500   16.0677
   6.014 14.6956       120
   8.877  9.9609       594
  12.432  7.1194       130
  17.762  4.9935       158
  20.953  4.2396       132
  24.964  3.5660       150
  26.714  3.3369       710


    65.500     1.4250
A5262+A5263C  12-04-1984  10.54  PROGRAM 214
```



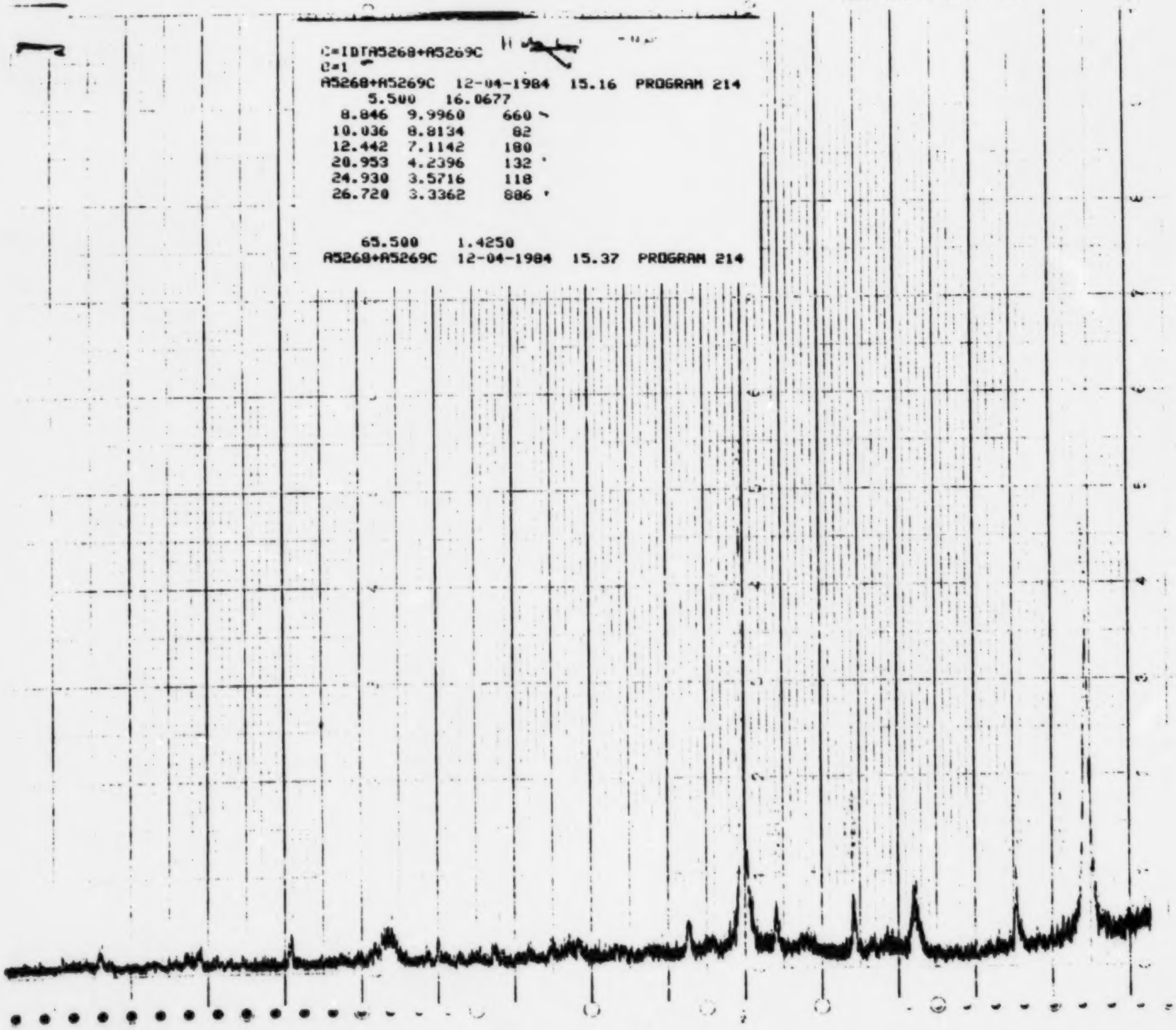
```
C=IDTA5264+A5265C [illegible] 12
C-1
A5264+A5265C  12-04-1984  12.07  PROGRAM 214
     5.500   16.0677
  8.882   9.9563      632
 12.446   7.1117      234
 13.364   6.6252      116
 17.765   4.9926      158
 20.953   4.2396       98
 24.961   3.5672      162
 26.760   3.3314      814


    65.500    1.4250
 A5264+A5265C  12-04-1984  12.28  PROGRAM 214
```



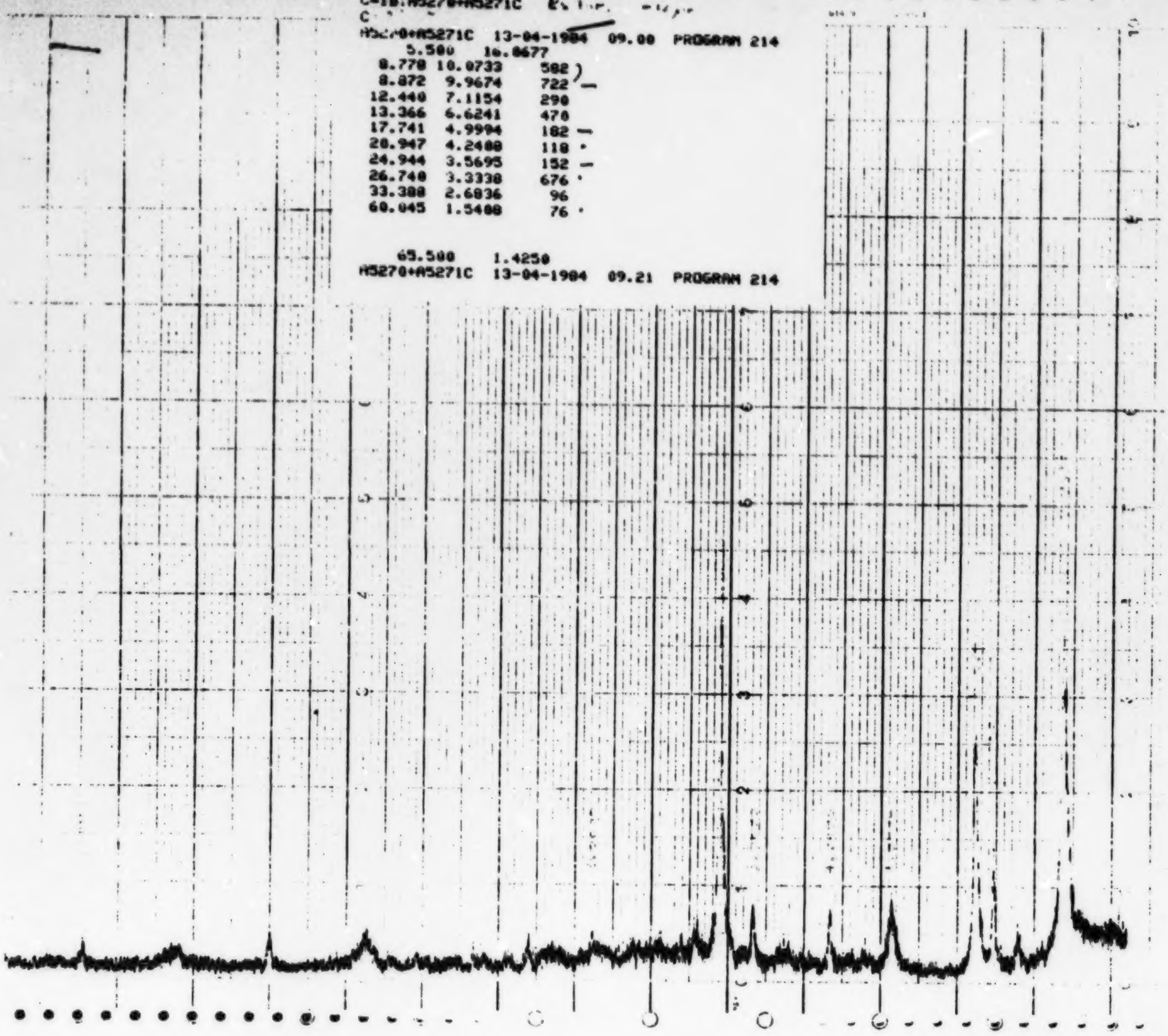
```
C IBTA5266+A5267C
C=1
A5266+A5267C  12-  1984  13.47  PROGRAM 2
     5.500   16.0
  8.851   9.9901    [illegible]
 12.455   7.1067    142
 20.967   4.2367    146 .
 26.740   3.3337    652 .


    65.500    1.4250
A5266+A5267C  12-04-1984  14.07  PROGRAM 214
```



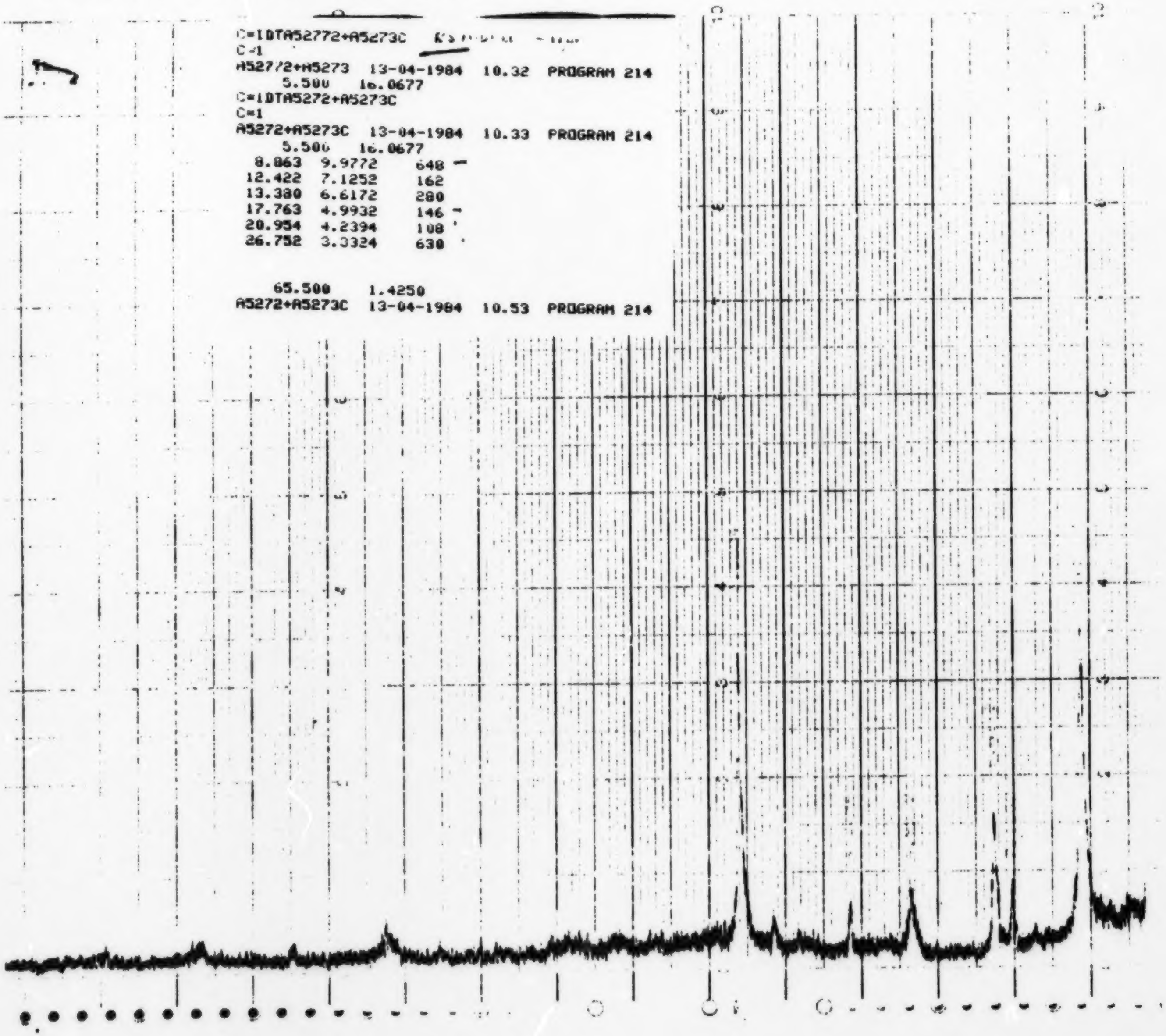
```
C=IDTA5268+A5269C
C=1
A5268+A5269C  12-04-1984  15.16  PROGRAM 214
     5.500   16.0677
  8.846   9.9960     660
 10.036   8.8134      82
 12.442   7.1142     180
 20.953   4.2396     132
 24.930   3.5716     118
 26.720   3.3362     886


    65.500    1.4250
 A5268+A5269C  12-04-1984  15.37  PROGRAM 214
```



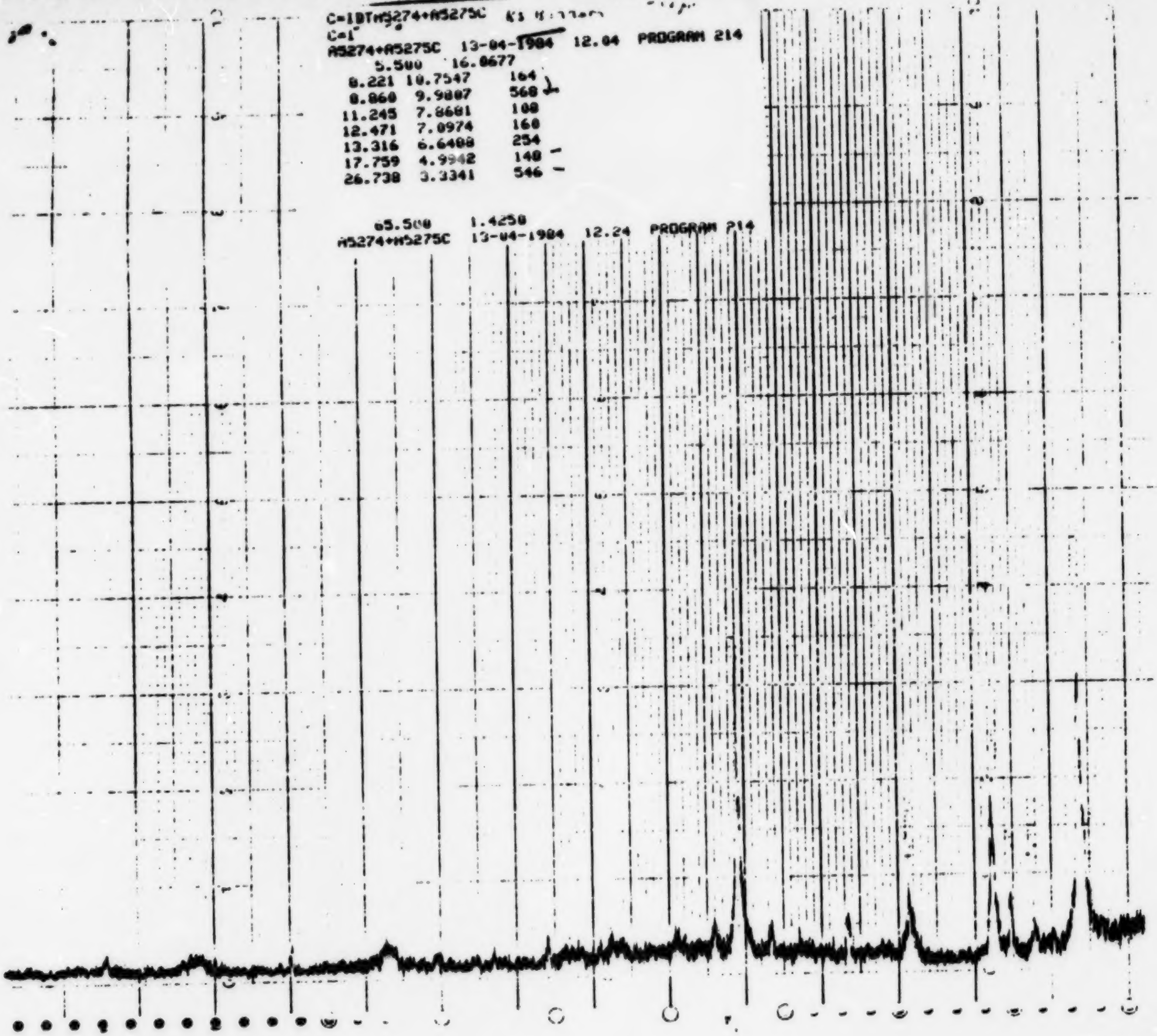
```
C=IBTA5270+A5271C
C
A5270+A5271C  13-04-1984  09.00  PROGRAM 214
     5.500   16.0677
   8.770 10.0733     502 )
   8.872  9.9674     722 —
  12.440  7.1154     290
  13.366  6.6241     470
  17.741  4.9994     102 —
  20.947  4.2400     110 ·
  24.944  3.5695     152 —
  26.740  3.3330     676 ·
  33.300  2.6836      96
  60.045  1.5400      76 ·

     65.500    1.4250
A5270+A5271C  13-04-1984  09.21  PROGRAM 214
```



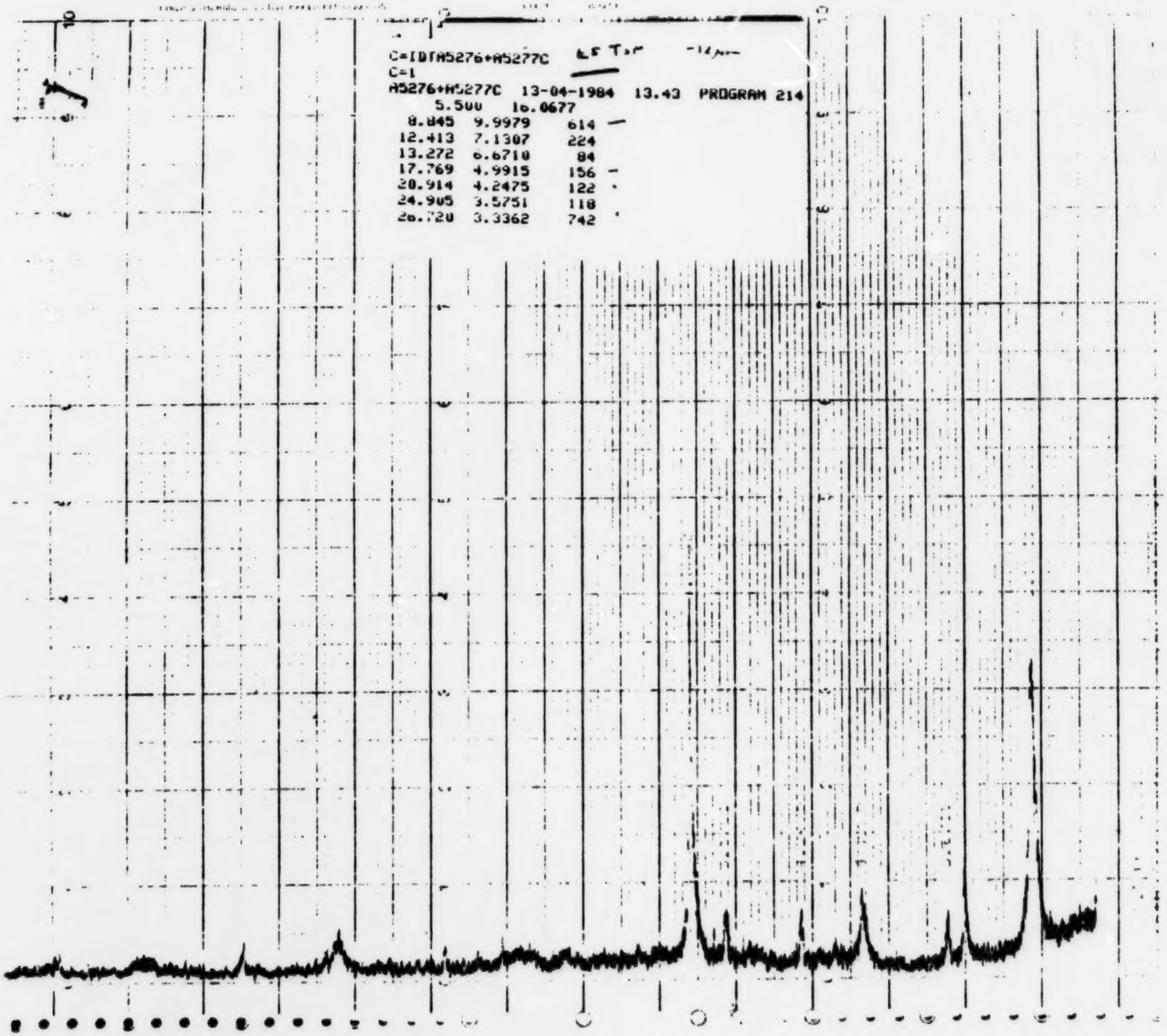
```
C=IDTA52772+A5273C
C-1
A52772+A5273  13-04-1984  10.32  PROGRAM 214
     5.500   16.0677
C=IDTA5272+A5273C
C=1
A5272+A5273C  13-04-1984  10.33  PROGRAM 214
     5.500   16.0677
  8.863  9.9772     648
 12.422  7.1252     162
 13.380  6.6172     280
 17.763  4.9932     146
 20.954  4.2394     108
 26.752  3.3324     630


    65.500    1.4250
A5272+A5273C  13-04-1984  10.53  PROGRAM 214
```



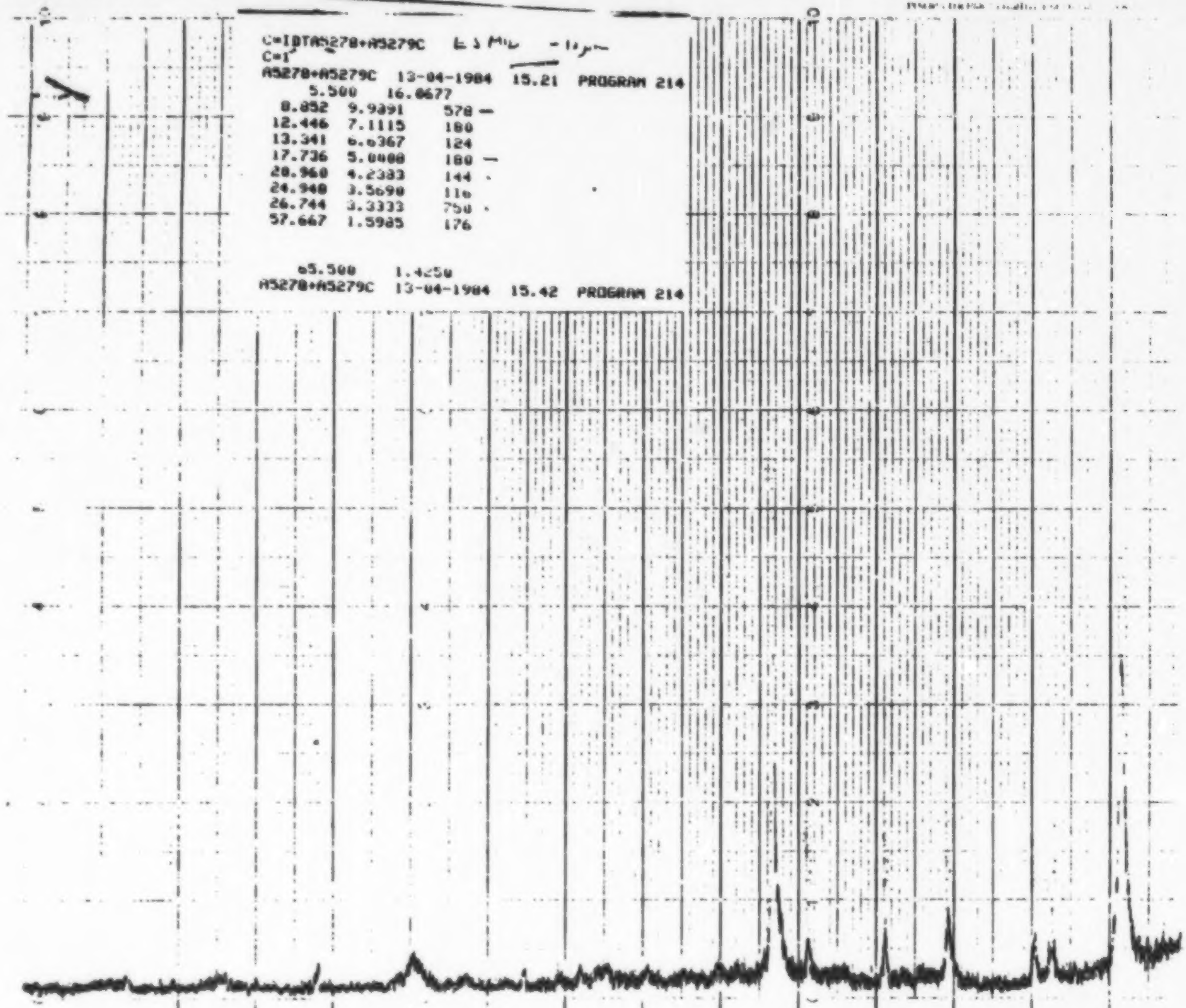
```
C=IDTA5274+A5275C   Ki [illegible]
C=1
A5274+A5275C   13-04-1984   12.04   PROGRAM 214
      5.500   16.0677
   8.221  10.7547      164
   8.860   9.9807      568
  11.245   7.8601      108
  12.471   7.0974      160
  13.316   6.6408      254
  17.759   4.9942      140 -
  26.738   3.3341      546 -

       65.500      1.4250
  A5274+A5275C   13-04-1984   12.24   PROGRAM 214
```



```
C=IDTA5276+A5277C
C=1
A5276+A5277C  13-04-1984  13.43  PROGRAM 214
     5.500   16.0677
  8.845  9.9979     614
 12.413  7.1307     224
 13.272  6.6710      84
 17.769  4.9915     156
 20.914  4.2475     122
 24.905  3.5751     118
 26.720  3.3362     742
```

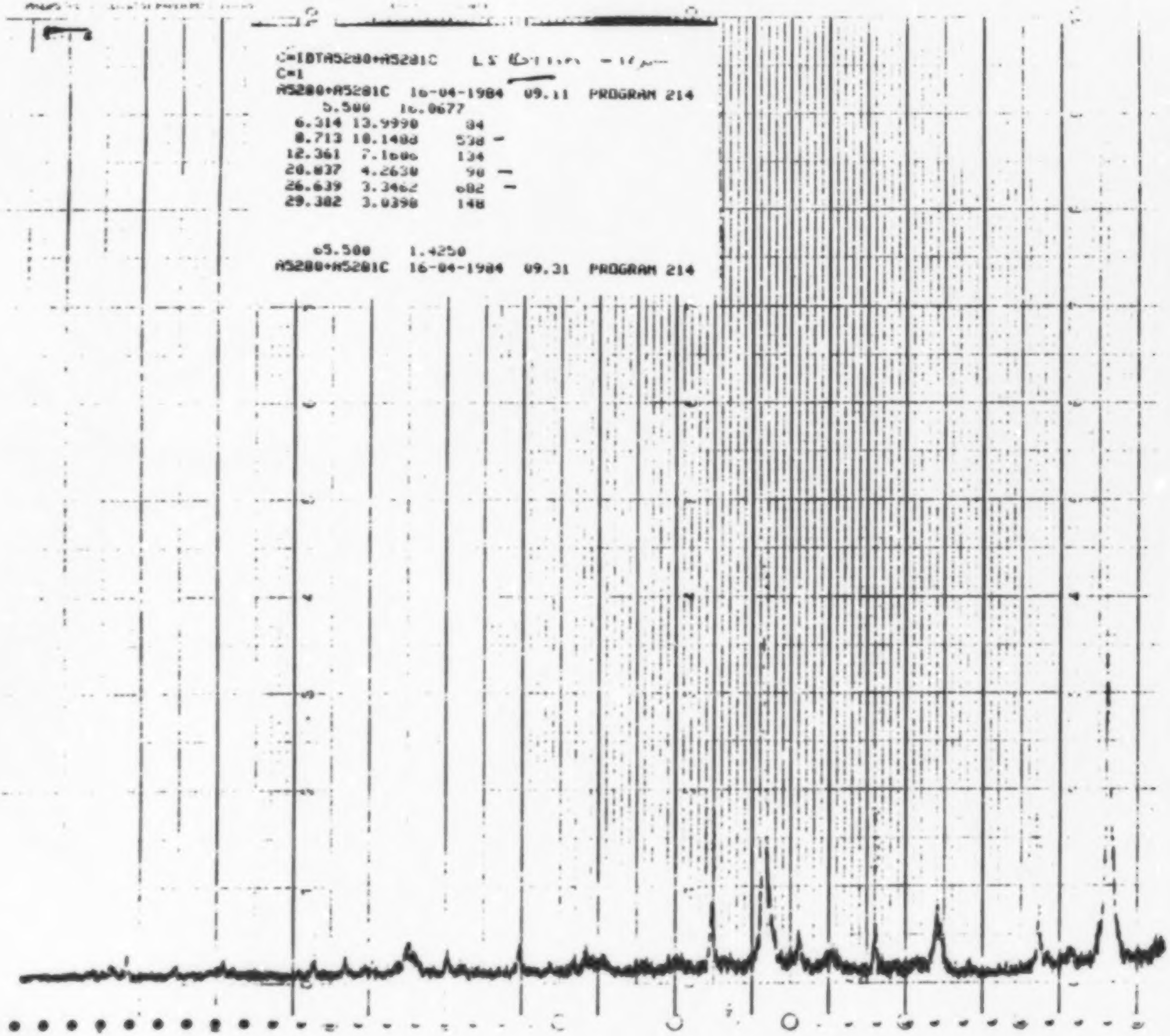
LS Tar -14μm



```
C=IDTA5278+A5279C
C=1
A5278+A5279C  13-04-1984  15.21  PROGRAM 214
     5.500   16.0677
   8.852   9.9891    578
  12.446   7.1115    180
  13.341   6.6367    124
  17.736   5.0000    180
  20.960   4.2383    144
  24.940   3.5690    116
  26.744   3.3333    750
  57.667   1.5985    176

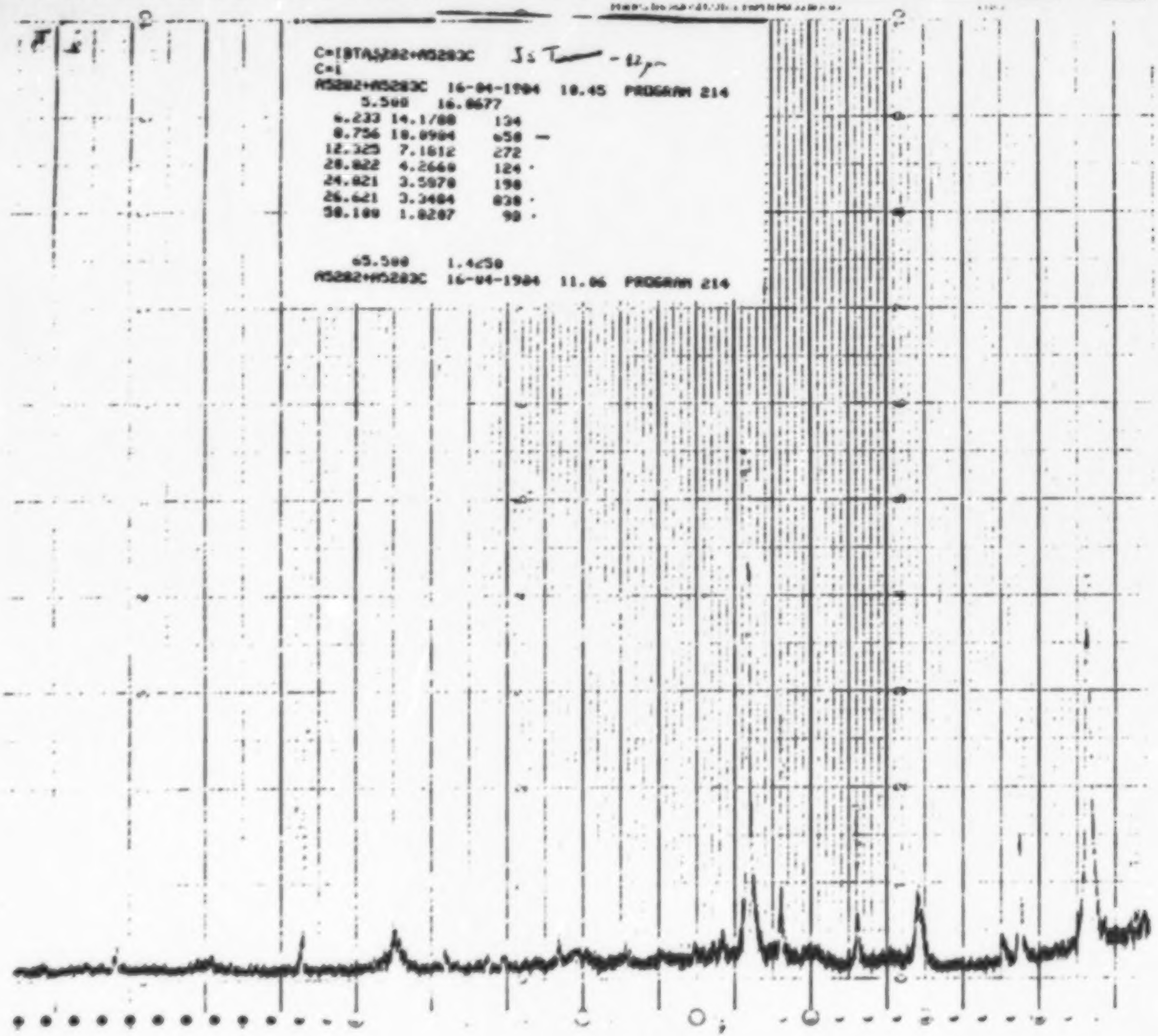

     65.500    1.4250
A5278+A5279C  13-04-1984  15.42  PROGRAM 214
```

E S MID - 11μm



```
C=IDTA5280+A5281C    LS Bottom - [illegible]
C=1
A5280+A5281C  16-04-1984  09.11  PROGRAM 214
      5.500   16.0677
   6.314 13.9990      84
   8.713 10.1488     538 -
  12.361  7.1606     134
  20.837  4.2630      98 -
  26.639  3.3462     682 -
  29.382  3.0398     148

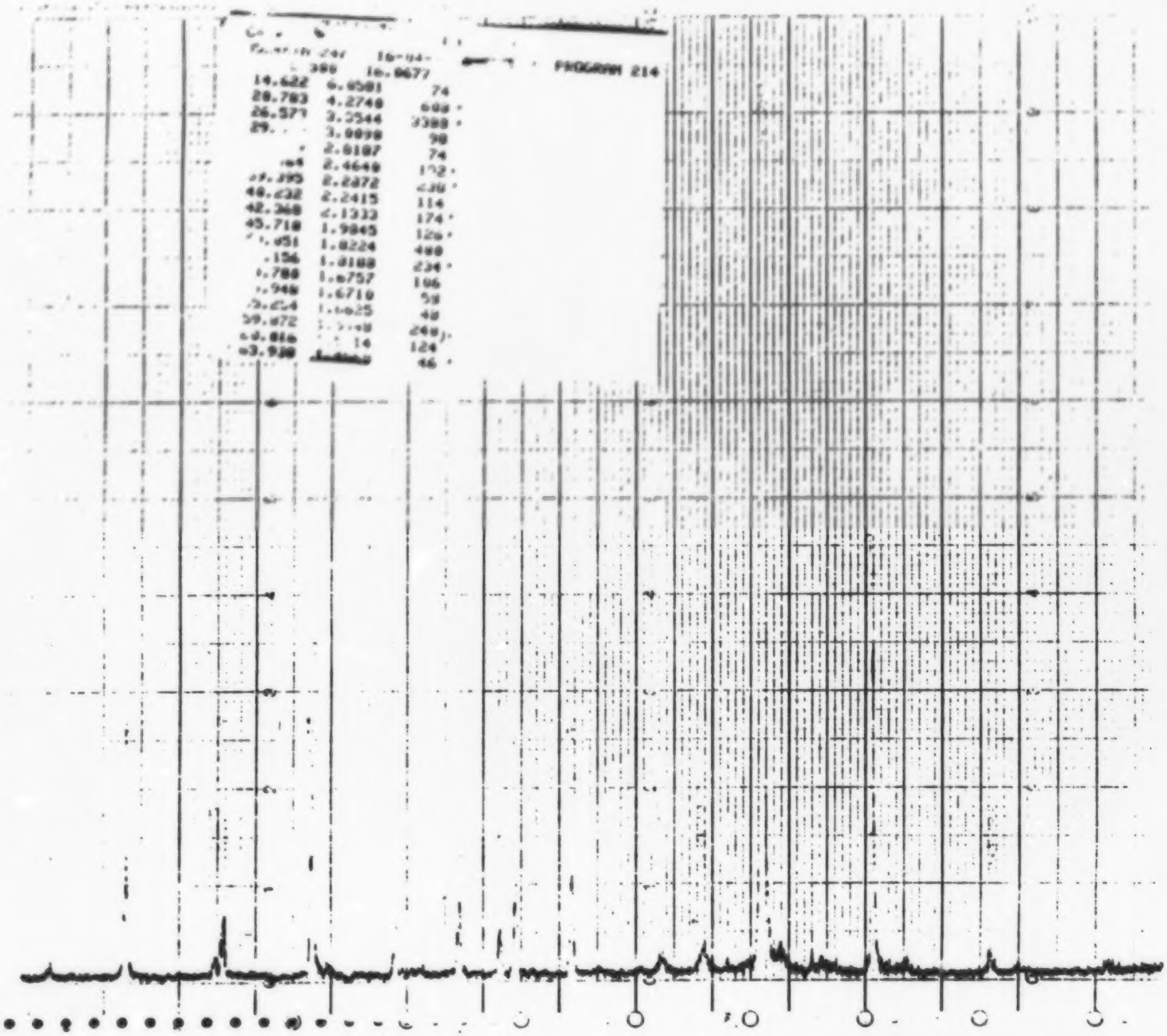

     65.500    1.4250
A5280+A5281C  16-04-1984  09.31  PROGRAM 214
```



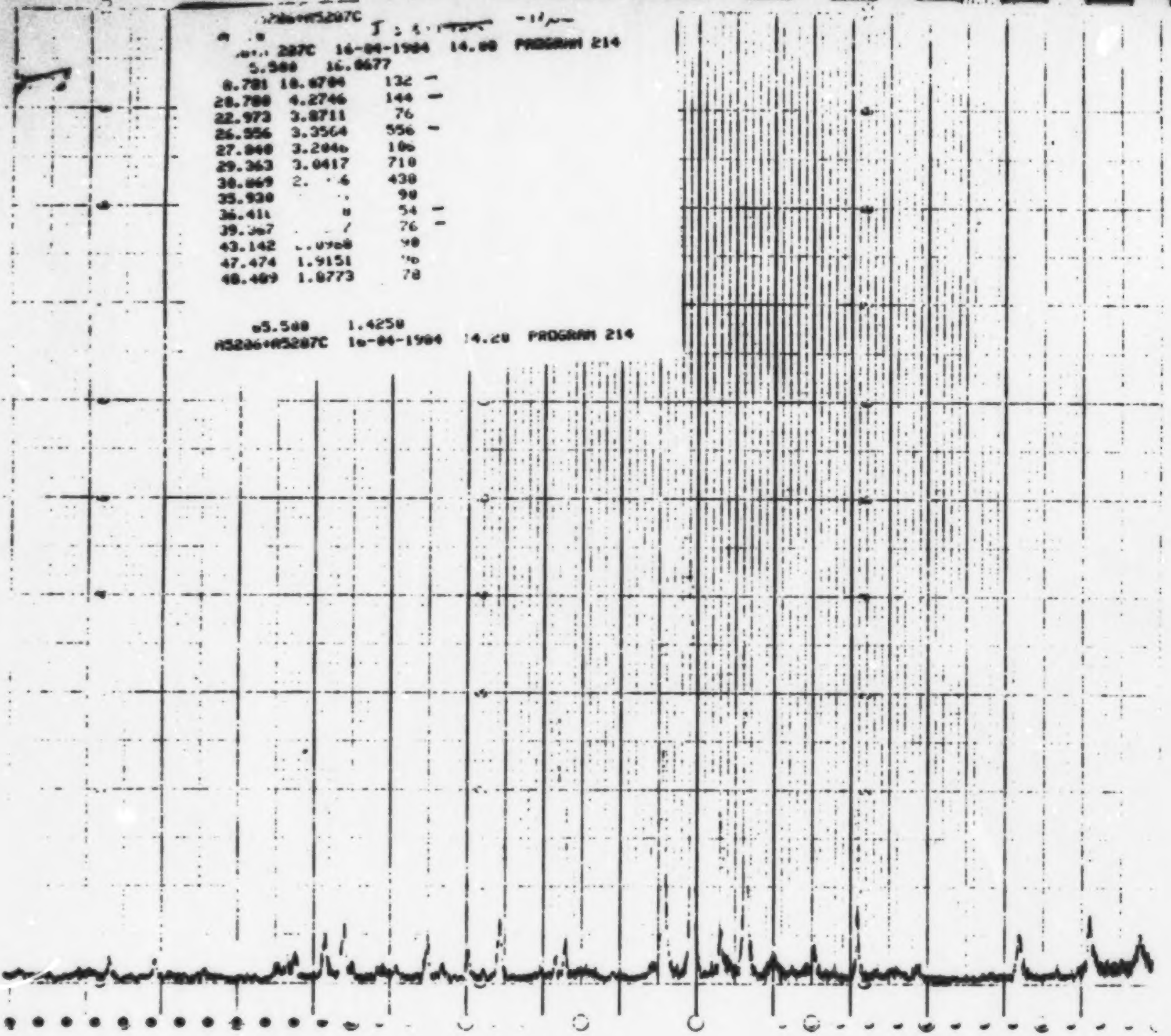
```
C=[BTA5282+A5283C
C=1
A5282+A5283C  16-04-1984  10.45  PROGRAM 214
     5.500   16.0677
   6.233 14.1788      134
   8.756 10.0984      658 —
  12.325  7.1812      272
  20.822  4.2660      124 ·
  24.821  3.5870      198
  26.621  3.3484      838 ·
  50.100  1.8207       98 ·

    65.500    1.4250
A5282+A5283C  16-04-1984  11.06  PROGRAM 214
```

Js T— - 12μm

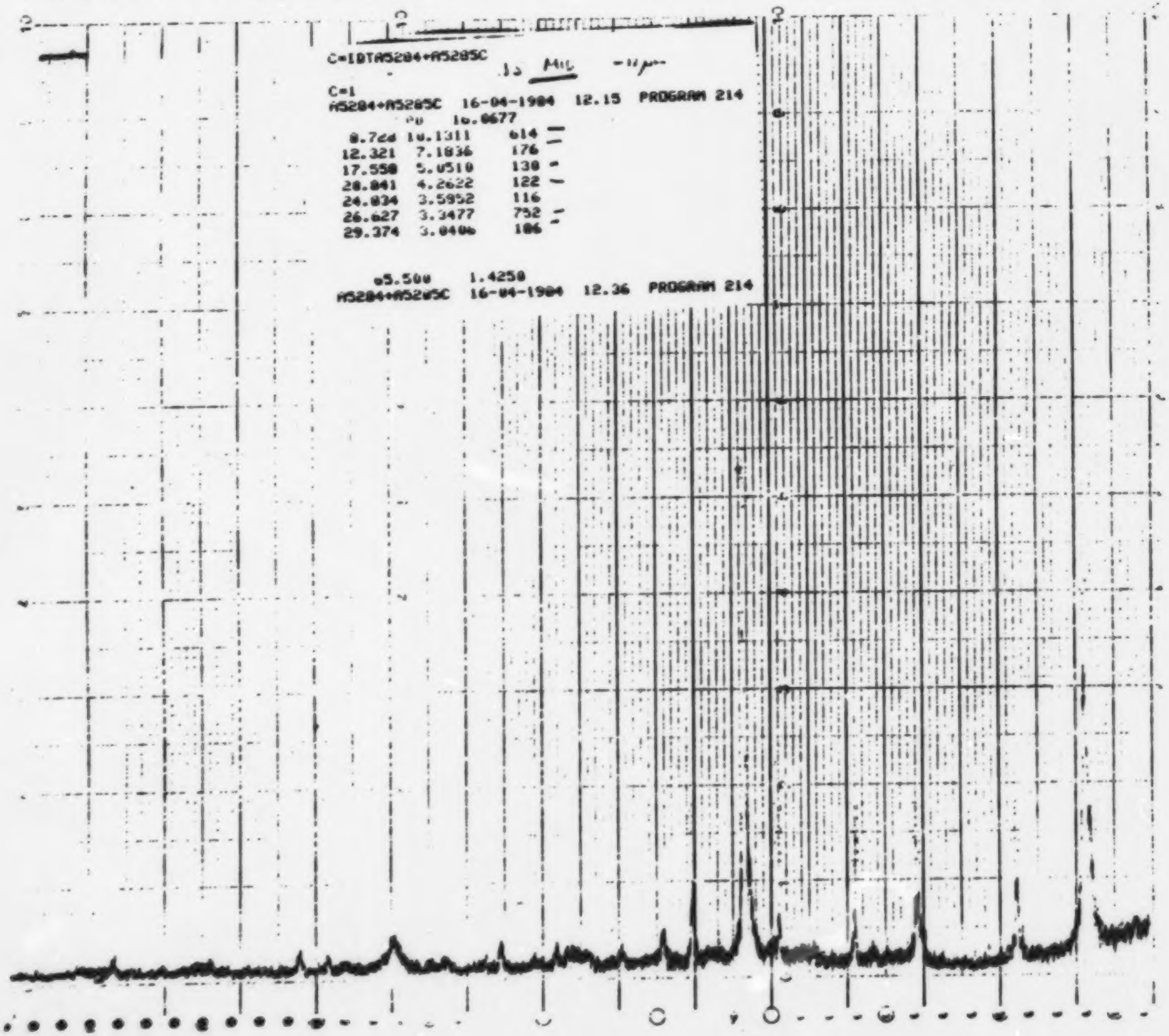


```
Co
Pa...n 24?   16-04-            PROGRAM 214
  . 380     16.0677
 14.622   6.0581      74
 20.783   4.2740     608 .
 26.577   3.3544    3388 .
 29.      3.0898      98
      .   2.6187      74
    .64   2.4640     102 .
 39.395   2.2872     230 .
 40.232   2.2415     114
 42.368   2.1333     174 .
 45.718   1.9845     126 .
   .051   1.8224     400
   .156   1.8188     234 .
   .788   1.6757     106
   .948   1.6710      59
   .214   1.6625      40
 59.872   [illegible]  248
 60.816   [illegible]  124
 63.930   [illegible]   46 .
```



```
[illegible]286+A5287C
[illegible] 287C   16-04-1984   14.00   PROGRAM 214
     5.500   16.0677
   8.781  10.0700     132 —
  20.780   4.2746     144 —
  22.973   3.8711      76
  26.556   3.3564     556 —
  27.840   3.2046     106
  29.363   3.0417     710
  30.869   2.[illegible]6     430
  35.930   [illegible]      90
  36.411   [illegible]      54 —
  39.367   [illegible]      76 —
  43.142   [illegible]      90
  47.474   1.9151      [illegible]
  48.409   1.8773      70

     65.500    1.4250
A5286+A5287C  16-04-1984  14.20  PROGRAM 214
```



```
C=IDTA5284+A5285C

C=1
A5284+A5285C   16-04-1984   12.15   PROGRAM 214
         Pu   10.0677
  8.720 10.1311       614
 12.321  7.1836       176
 17.550  5.0510       130
 20.841  4.2622       122
 24.834  3.5952       116
 26.627  3.3477       752
 29.374  3.0406       186


    05.500     1.4250
A5284+A5205C   16-04-1984   12.36   PROGRAM 214
```

.15 Mic -11μm

Canada Centre for Mineral
and Energy Technology
Final Report

APPENDIX Q

LYSIMETER AND CORE PHOTOGRAPHS

ONTARIO**RESEARCH**
FOUNDATION

Energy

energy conservation programs and analyses, thermal insulation design and evaluation, waste heat recovery, building energy systems and monitoring, heat storage systems and materials, thermoelectric generation, combustion technology, burner development, heat transfer analysis, solar systems monitoring, National Solar Test Facility, solar technology, wind power, coal, lignite and oil sands processing, alternate fuel utilization, battery and fuel cell technology, peat processing and utilization, fenestration measurements, heat pump development and test facilities, residential heating systems, air to air heat exchange test facility, photovoltaic devices, . . .

Environment

ambient air quality assessment, environmental impact assessments, long-range transport of atmospheric pollutants, precipitation chemistry, particulate characterization studies, emission inventories, source sampling, odour emission and control, asbestos measurement and control, occupational health and safety studies, diesel emission control technology, air pollution control, pesticide residues, trace metal analysis, trace organic analysis, radionuclide analysis, mutagenic testing, noise and vibration analysis, radiation measurements, particulate identification and measurement, water surveys, water purification, industrial and municipal wastewater treatment, membrane separation techniques, wet oxidation, solid waste treatment and recovery, hazardous waste treatment and disposal, indoor air quality assessments, priority pollutant analysis, landfill technology, . . .

Materials

building materials, plastics, composites, metals, glass and ceramics, wood and wood composites, biomaterials, adhesives and printing inks, fibres, yarns, fabrics and geotextiles, leather, organic and inorganic chemicals, specification development, quality assurance, mechanical, chemical and thermal properties, test method development, failure analysis, fire and flammability, glass-metal seals, metal and alloy powders, metallography, materials characterization, materials characterization by optical and electron microscopy and X-ray microanalysis, photovoltaic materials, materials corrosion resource centre, corrosion properties and control, bacterial corrosion, coatings and sealants, rubber technology, X-ray analysis, cement and concrete, soils and aggregates, gypsum, body armour testing, footwear, paper-making materials, roofing and waterproofing, waste material stabilization and solidification, . . .

Products & Processes

clothing, footwear and industrial textile products, knitting technology, thin and thick film systems, microelectronics development, fibre optics, instrumentation, bioengineering, ultrasonic and fluid shear devices, microwave drying, transportation and equipment testing, mathematical stress and vibration analysis, product, equipment and machinery design & development, fuel emulsification, organic analysis and characterization, chemistry of foodstuffs, pulp and paper processes, ceramics processing, metallurgical process development, powder metal technology, packaging applications, technical and economic evaluations, industrial engineering applications, process control, enzyme analysis, electrical testing, radioactive surveys, industrial microbiology, biotechnology, technical and management skills development seminars, paper products, absorbent consumer products, detergent and cosmetic formulation, metal chemical analysis, flash hydropyrolysis of coal, electroplating, . . .

Resources

mineral processing, hydro and pyrometallurgical processing of ferrous and non-ferrous ores, coal evaluation, coal ash utilization and product development, asbestos processing and applications, non-metallic minerals/industrial minerals processing and utilization, uranium processing, forest utilization, utilization of forest and agricultural wastes, utilization of industrial, mining and domestic wastes, energy and chemicals from biomass, in-plant waste reduction, mineralogical services, mining and metallurgical waste disposal, . . .

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